AHAS - Aviation Hazard Awareness System

Design and Flight Testing of a Prototype AWIN System for Transport Aircraft

Weather Accident Prevention
Third Annual Review
November 20-21, 2002

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Presentation Outline

- Introduction
- Background
- Flight Experiment Configuration
- Flight Test Results
- FY-03 Flight Experiment Plans
- Conclusions

Aviation Safety Program Office

Ruth Martin, Acting Director
George Finelli, Deputy Director
Glenn Bond, Senior Prog Analyst
Connie Smith, Secretary
Brian Smith, Dep Prog Mgr (ARC) Doug Rohn, Dep Prog Mgr (Acting, GRC)

Technical Integration
Frank Jones
(LaRC)

Program Integration
Michael Basehore (FAA)
Carrie Walker (HQ)

Thrust Areas

- 1.3 Vehicle Safety Technology
- 1.4 Weather Safety Technology
- 1.5 Systems Safety Technology

Projects

- 2.3 Single Aircraft Accident Prevention John White (LaRC)
- 2.6 Synthetic Vision Daniel Baize Cheryl Allen (LaRC)
- 2.5 Accident Mitigation Robert McKnight (GRC)
- 2.4 Weather Accident Prevention K. Martzaklis (GRC)
- 2.7 Aircraft Icing Mary Wadel (GRC)
- 2.1 Aviation System Monitoring & Modeling Irving Statler (ARC)
- 2.2 System-Wide Accident Prevention Tina Beard (ARC)
- 2.8 Search and Rescue David Affens (GSFC)

Elements

- Aviation Weather Information (AWIN) — Paul Stough (LaRC)
- Weather Information Communications (WINCOMM) — Mike Jarrell (GRC)
- Turbulence Prediction & Warning Systems (TPAWS) — Rod Bogue (DFRC), Jim Watson, Dep (LaRC)

WxAP/AWIN/AHAS Milestones

- Milestone 11: Initial AHAS Flight Evaluation
  - Completed on ARIES 2002 with AHAS
- Milestone 14: AHAS Flt Eval w/ Cockpit Display
  - Scheduled for 2003 Deployment

- EWxR and AWARE Cooperative Research Agreements (CRAs)
  - Negotiated between NASA and Rockwell Science Center (now Rockwell Scientific) and involving Rockwell Collins
  - AWARE: Aviation Weather Analysis and Reporting Enhancements
    - Originally intended as a General Aviation (GA) pre-flight briefing tool
  - EWxR: Enhanced Weather Radar
    - Combines airborne weather radar with datalinked information
    - Flight tested on Rockwell and NASA aircraft
    - Flown on NASA B-757 Airborne Integrated Research Experiment System (ARIES) in 2000 & 2002
- AHAS is a NASA-sponsored program conducted jointly by Rockwell Scientific, Rockwell Collins, and NASA
  - Combines EWxR and AWARE CRA technologies into an in-flight weather analysis tool

Current AHAS Rockwell Principals

- **Rockwell Scientific**

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  Rockwell Collins Advanced Technology Center
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Aviation Hazard Awareness System (AHAS) Background

AvSP / Weather Accident Prevention / Aviation Weather INformation

- **AHAS is an enhanced weather analysis tool, integrating text-based and graphical weather data for superior situational awareness in the context of a specific mission and equipment profile**
- **Initial flight evaluation on NASA B-757 Airborne Integrated Research Experiment System (AIRES) in FY-2002**
  - First-generation prototype AWIN system
  - Evaluation by researchers - no cockpit display
- **AHAS Tactical Mode: Enhanced Airborne Weather Radar**
  - Derived from EWxR CRA technologies
  - Real-time EWxR displays
  - Pilot can select combinations of WxR, NEXRAD, Attribute Data
  - Radar data collection for additional post-flight processing
- **AHAS Strategic Mode: Moving Map Display**
  - Derived from AWARE CRA technologies
  - Real-time hazard analysis on datalinked weather information
  - Strategic display of flight-path relevant weather hazards

Why decision aids?

Complexity of information: Pilots must first parse & translate WMO codes, then draw on training and experience to interpret.

Volume of information: Pages of text are the norm for pre-flight briefing. Future proliferation of graphical weather products may increase difficulty of monitoring relevant weather.

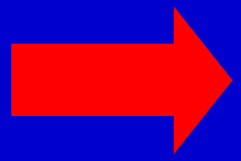
Reduction in workload/training: Pilots receive training in meteorology; Decision aid can reduce reliance on training.

AHAS is designed to benefit pilots (or dispatchers) who, due to cognitive overload, may not absorb and retain all flight-critical weather information from the vast (cryptic) stream of data they are legally required to review…

KTRM 022352Z 12006KT 25SM FEW200 SCT250 25/03 A2988 RMK SLP117 10261 20219 56015
KBUO 022346Z 29009KT 7SM SKC 18/14 RMK MAX 68 NOSPECI
KRIV 022355Z 28006KT 3SM HZ FEW000 19/11 A2995 RMK SLP133 HZ FEW000 56008
KRAL 022346Z 28012KT 7SM SKC A2993
KONT 022346Z 22008KT 6SM HZ FEW000 23/08 A2993 RMK HZ FEW000
KNXP 022355Z 00000KT 7SM FEW200 20/02 A2995
RMK SLP121 8/001 T02000022 10200 20128 56019

WHAT YOU GET NOW...

- TAFs
- METARs
- FAs
- AIRMETs
- SIGMETs
- NOTAMs
- PIREPs
- Winds Aloft
- NEXRAD images
- on-board WXR
- ...



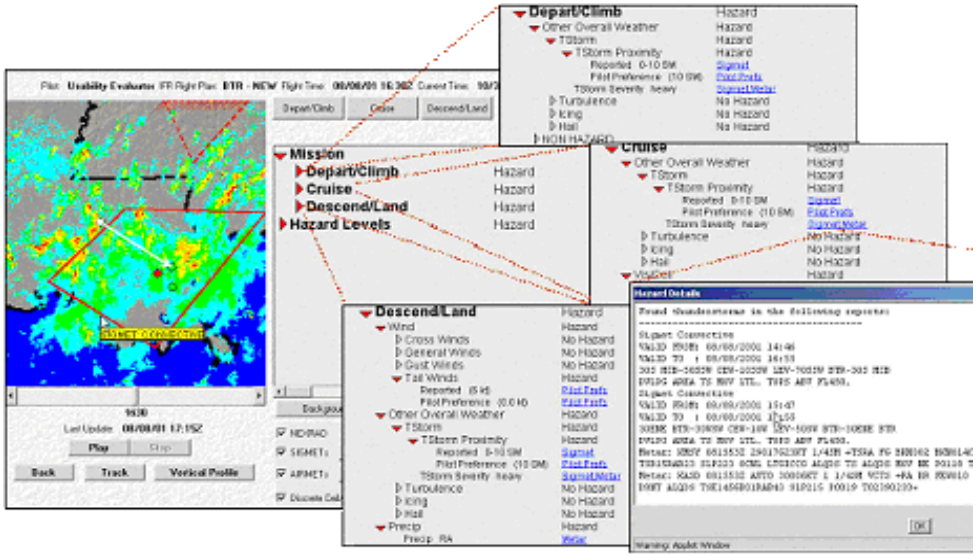
WHAT YOU REALLY NEED TO KNOW ...

Can I safely complete my mission without encountering weather hazards?

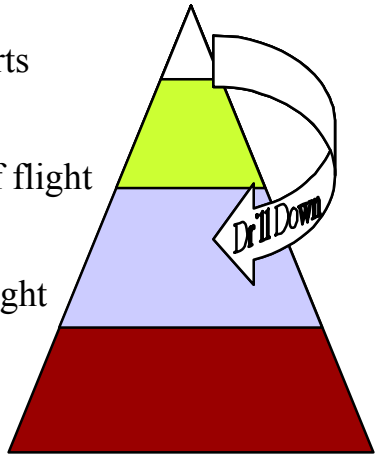
AHAS/AWARE Decision Analysis

AvSP / Weather Accident Prevention / Aviation Weather INformation

- One aspect of information filtering.
- Applies user/equipment constraints.
- User still has access to raw data.

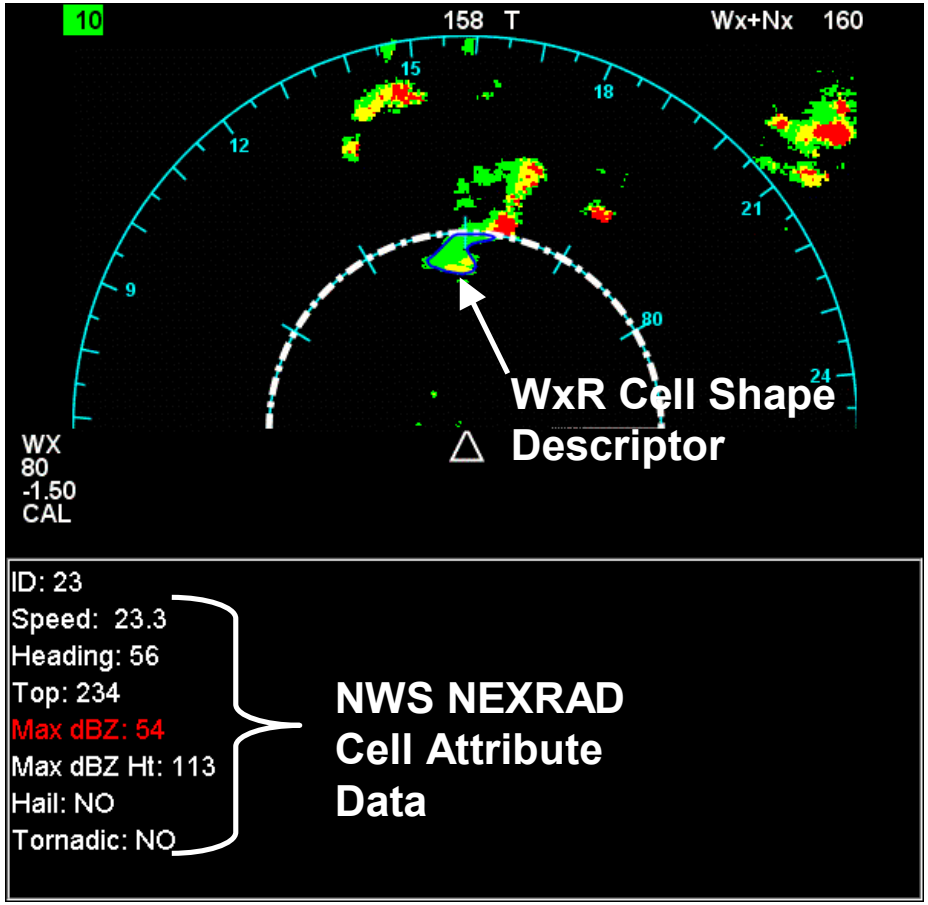


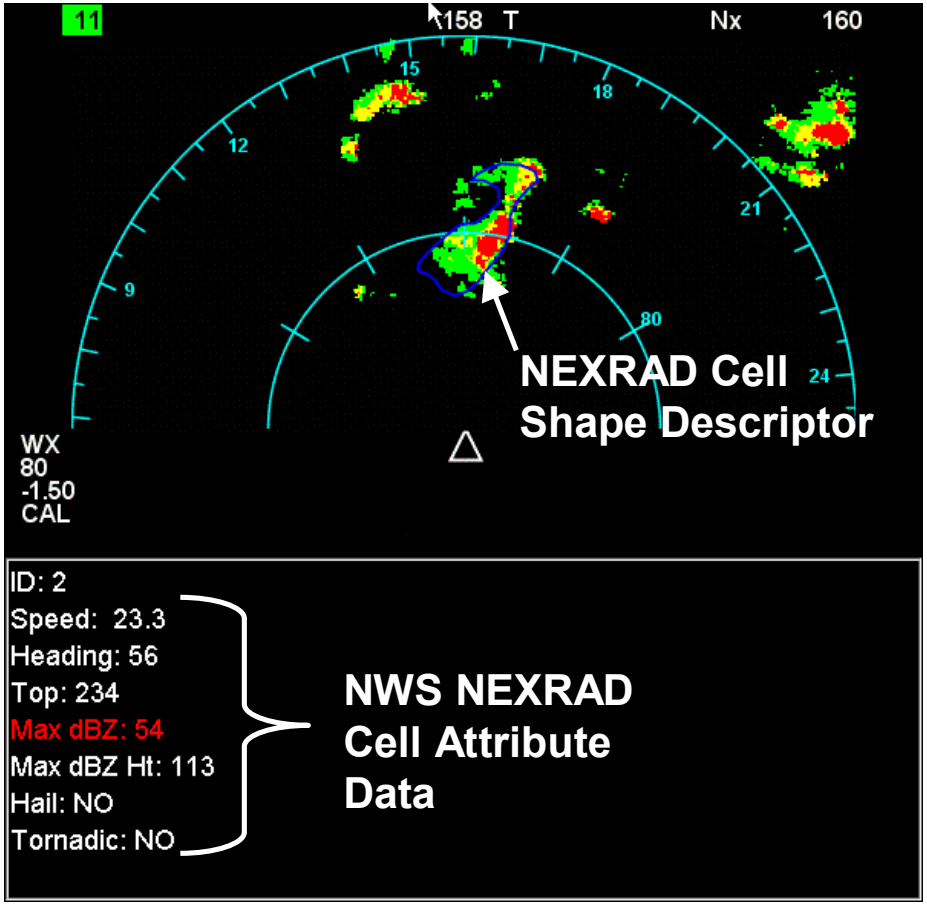
Filtered to:	Number of reports:
Actual Alerts	5
Location of flight	16
Time of Flight	5515
Full Day	25410



AHAS Tactical WxR/NEXRAD Data Correlation

AvSP / Weather Accident Prevention / Aviation Weather INformation

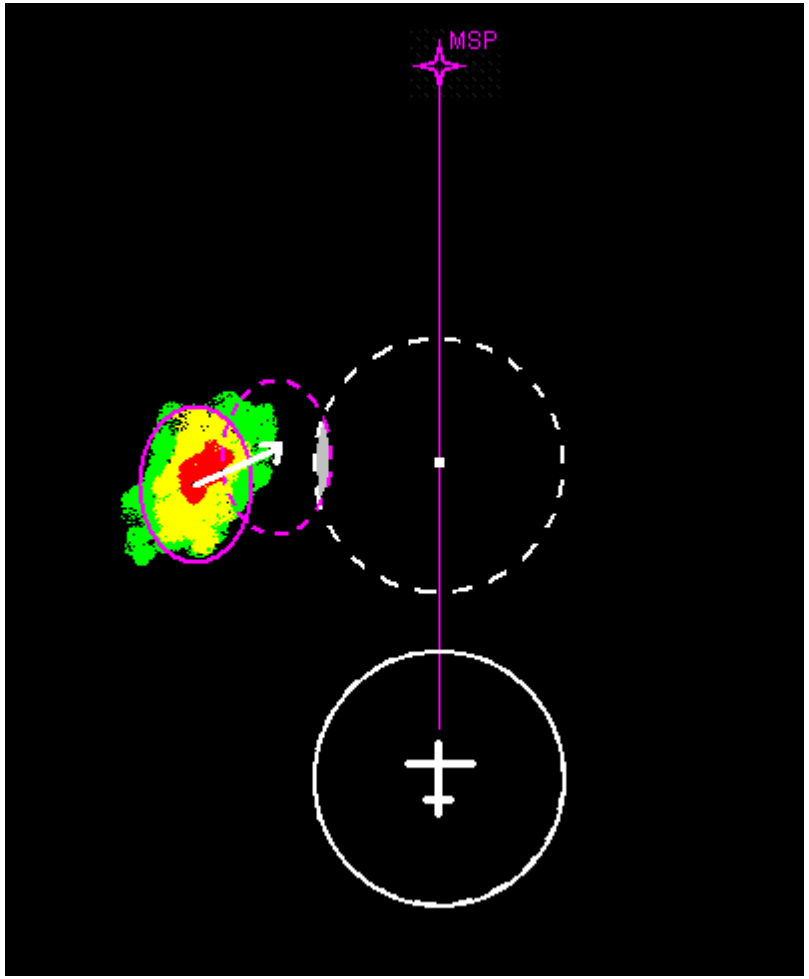




AHAS/EWxR Decision Aids

AvSP / Weather Accident Prevention / Aviation Weather INformation

- Hazard Avoidance and Flight Path Impact Prediction algorithm automatically determines hazardous regions along flight plan.
- Operates in real time with dynamic data.



AHAS/EWxR on FY-02 WxAP Integrated Flight Experiments

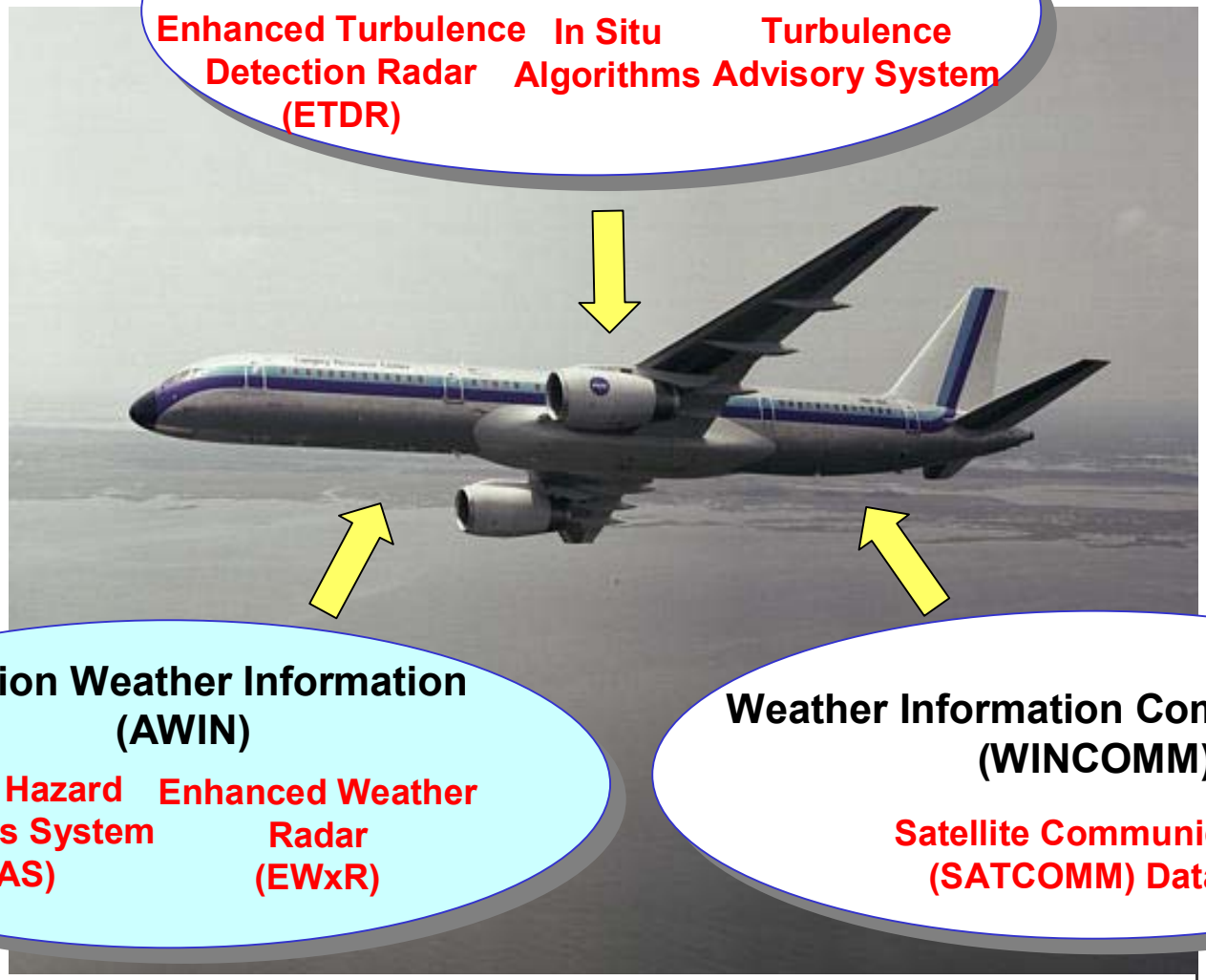
AvSP / Weather Accident Prevention / Aviation Weather INformation

Turbulence Prediction & Warning Systems (TPAWS)

Enhanced Turbulence Detection Radar (ETDR)

In Situ Algorithms

Turbulence Advisory System



Aviation Weather Information (AWIN)

Aviation Hazard Awareness System (AHAS)

Enhanced Weather Radar (EWxR)

Weather Information Communications (WINCOMM)

Satellite Communication (SATCOMM) Datalink

- FY-02 AHAS/EWxR Flight Test Objectives
  - Operational evaluation of the Aviation Hazard Awareness System and Enhanced Weather Radar system
  - Collect data to further develop AHAS concepts
  - Verify NEXRAD attribute data and other datalinked weather products
- SATCOM datalink provided by NASA Glenn WINCOMM program

AHAS/EWxR FY-02 Accomplishments

AvSP / Weather Accident Prevention / Aviation Weather INformation

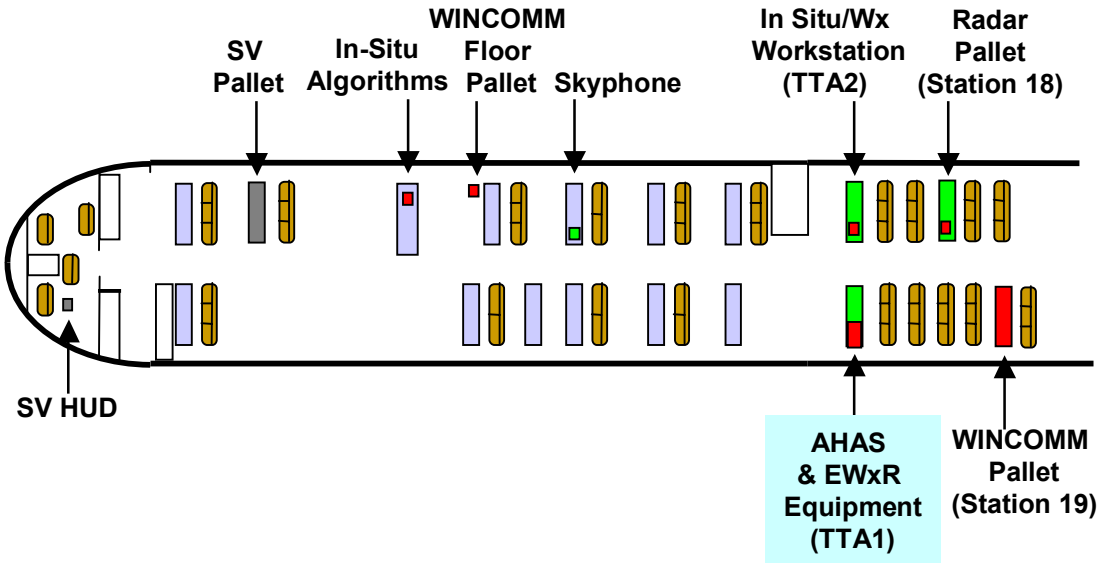
- Installed AHAS on NASA B-757 ARIES
- Conducted flight experiments to collect weather, aircraft, and radar data and assess overall system performance using research displays in the aft cabin of the B-757
- AHAS and EWxR operated on 15 flights in 2002 and extensive data was collected
- Verified data-linked storm-top information, turbulence indications, and SIGMET hazard areas using airborne weather radar, in situ information, visual, and meteorological observations

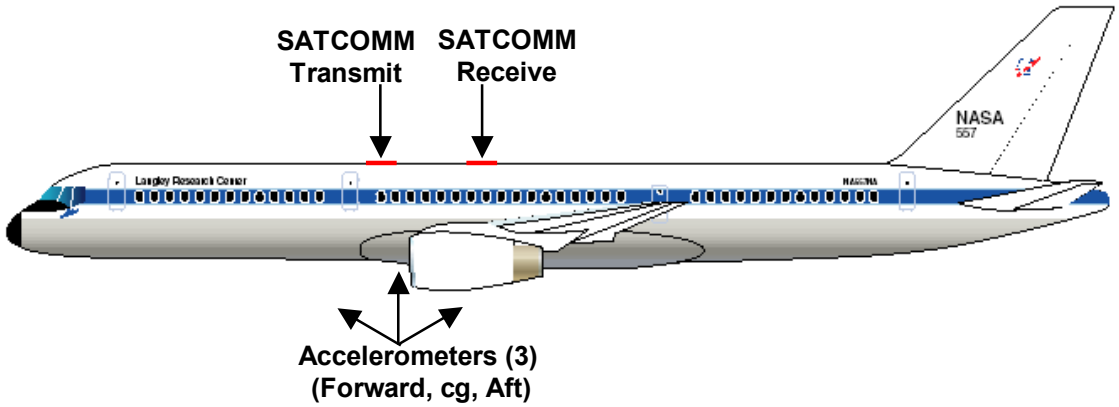
AHAS/EWxR FY-02 Accomplishments (Continued)

- Preliminary evaluation supports the utility of the AHAS system in increasing strategic and tactical situational awareness of weather hazards via successful demonstration of:
  - Correlation/Data fusion of airborne and ground-based weather information.
  - Automated Hazard Assessment and Flight Path Impact Decision Aids.

AHAS/EWxR B-757 ARIES Installation

AvSP / Weather Accident Prevention / Aviation Weather INformation





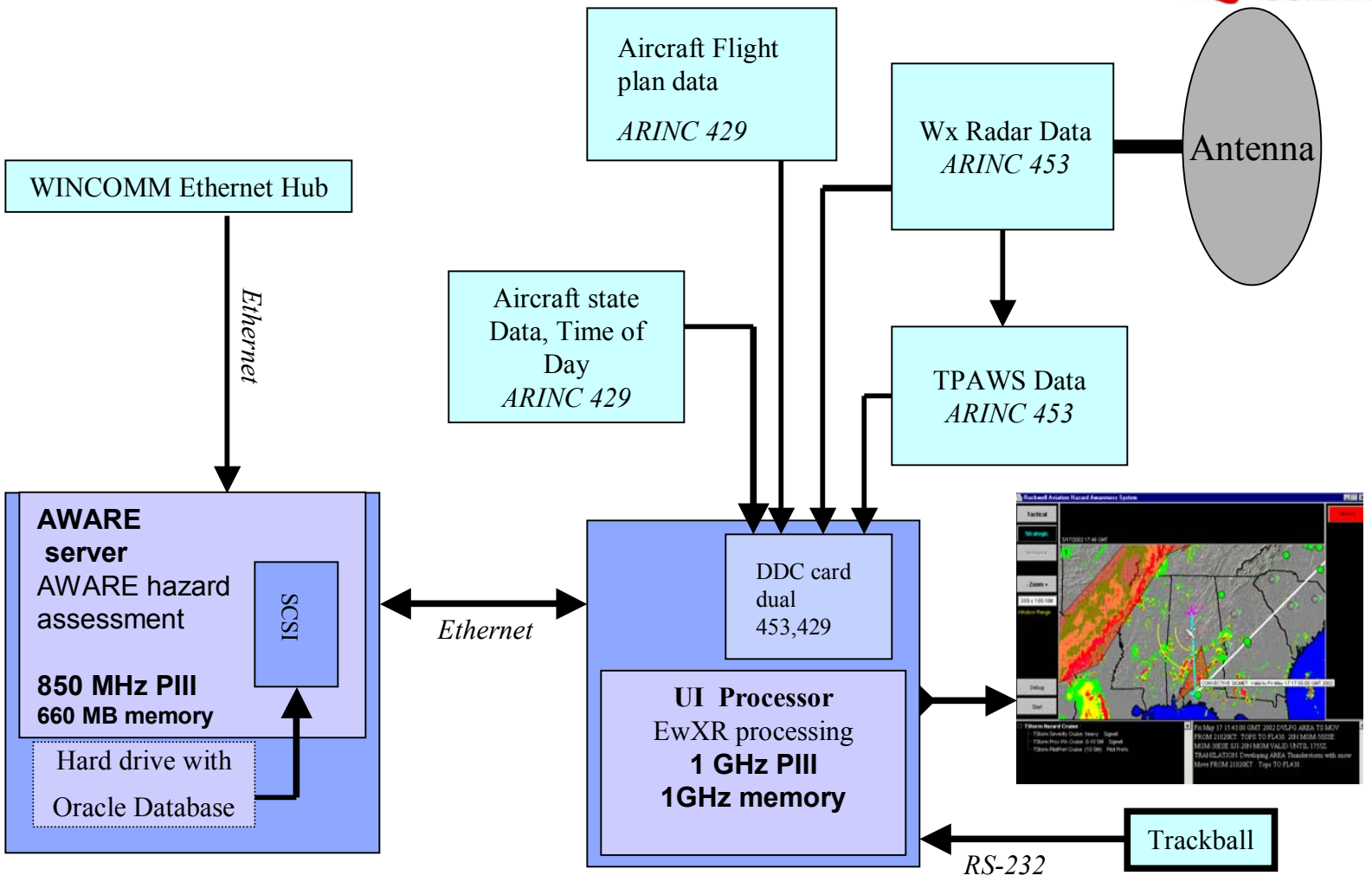
AHAS/EWxR ARIES Installation

AvSP / Weather Accident Prevention / Aviation Weather INformation

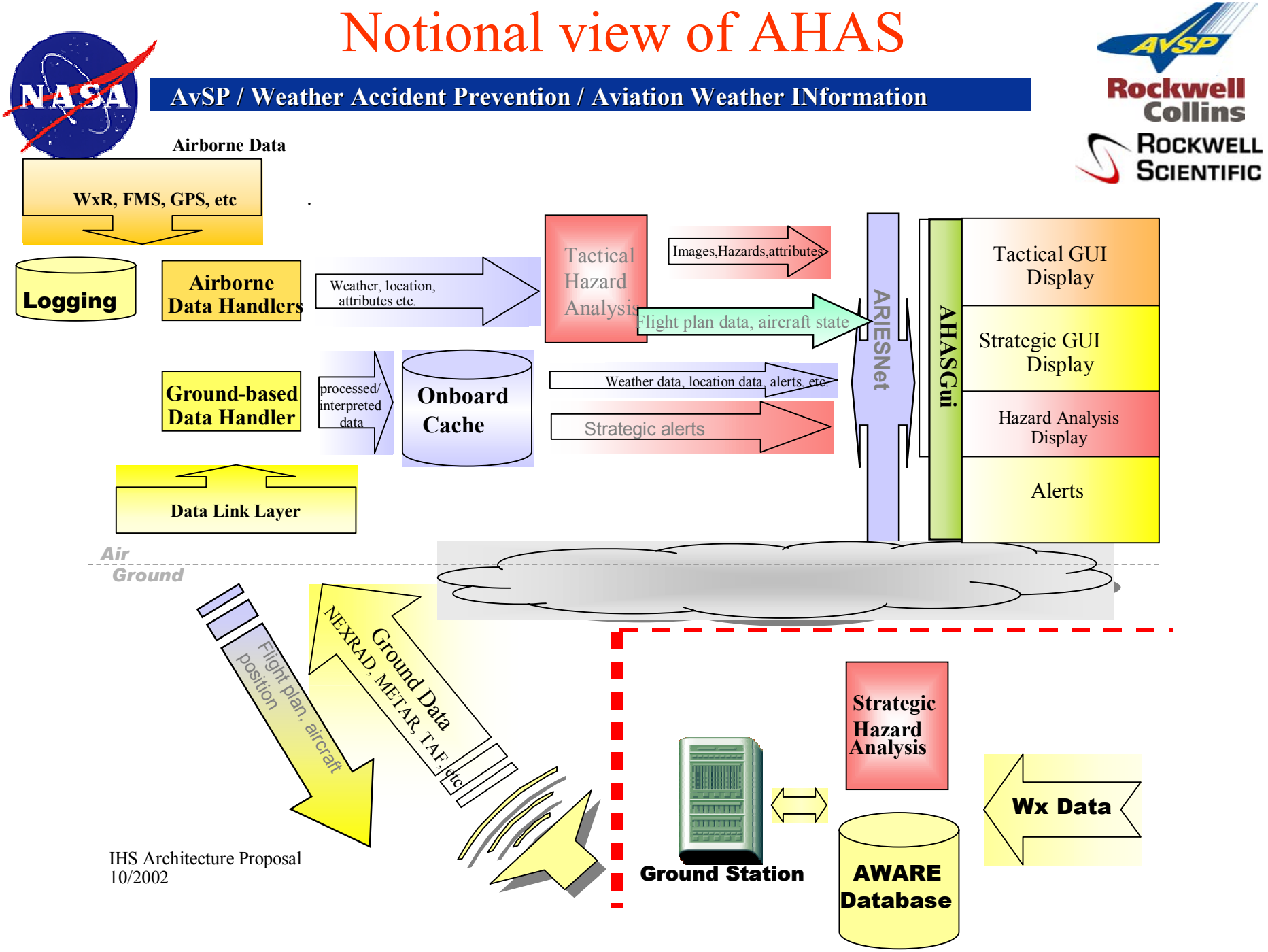
AWIN Modifications at TTA1 Pallet

AHAS FY-02 System Block Diagram

AvSP / Weather Accident Prevention / Aviation Weather INformation



Notional view of AHAS



IHS Architecture Proposal
10/2002

AHAS – Strategic Display

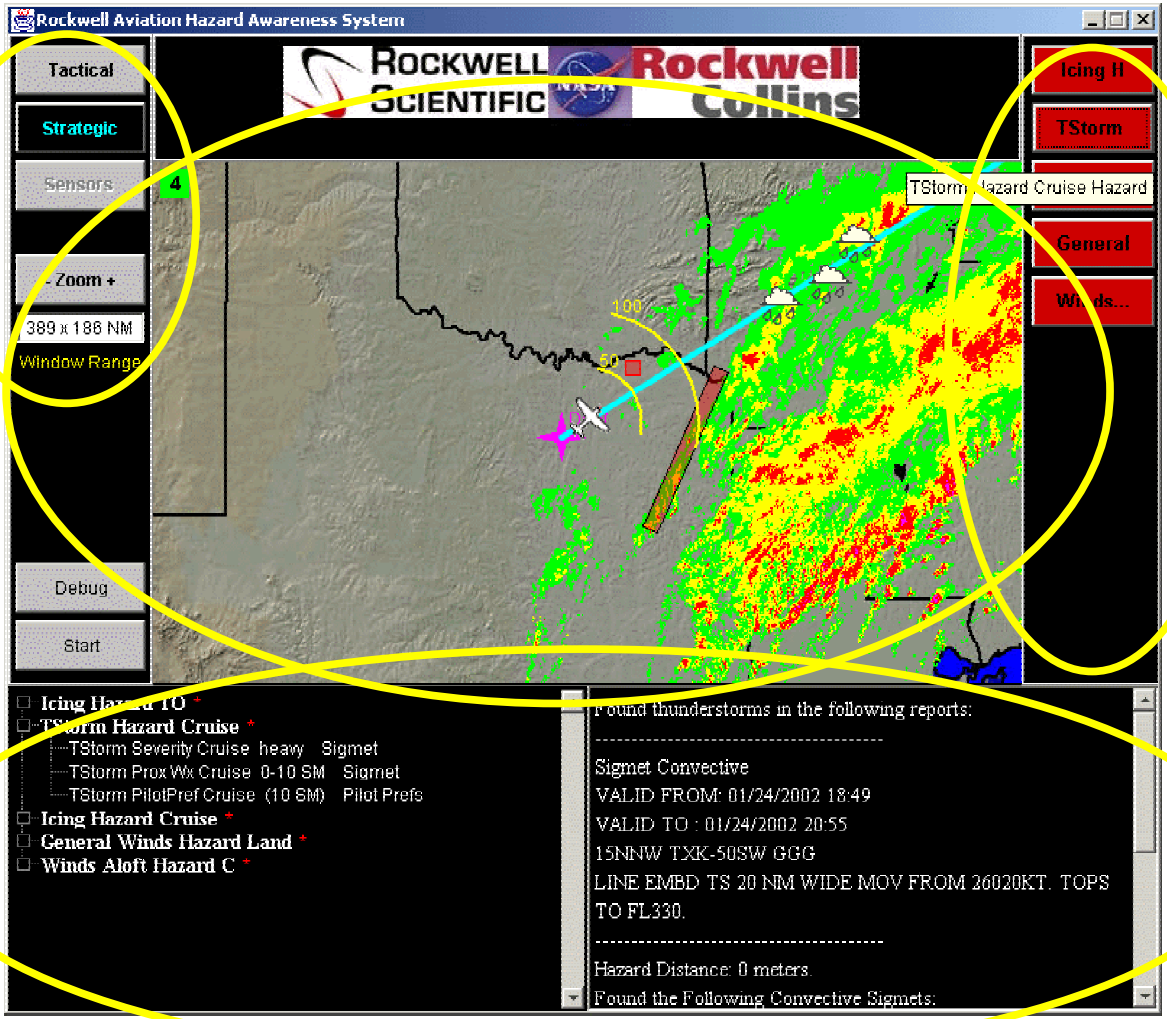
AvSP / Weather Accident Prevention / Aviation Weather INformation

Primary Display: Strategic mode similar to AWARE

Mode control: Strategic or Tactical

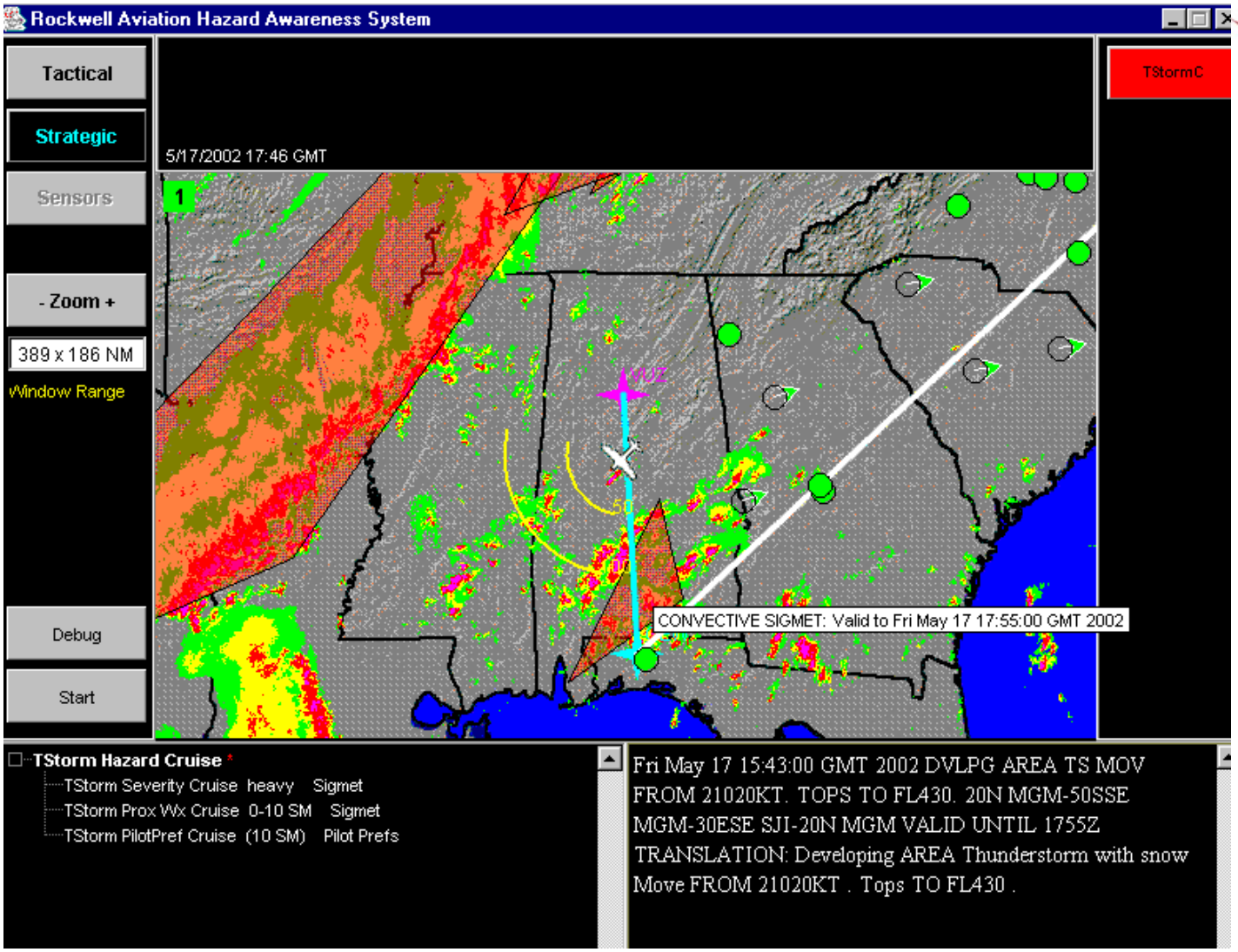
Alerts

Secondary Displays: Decision Analysis & data source

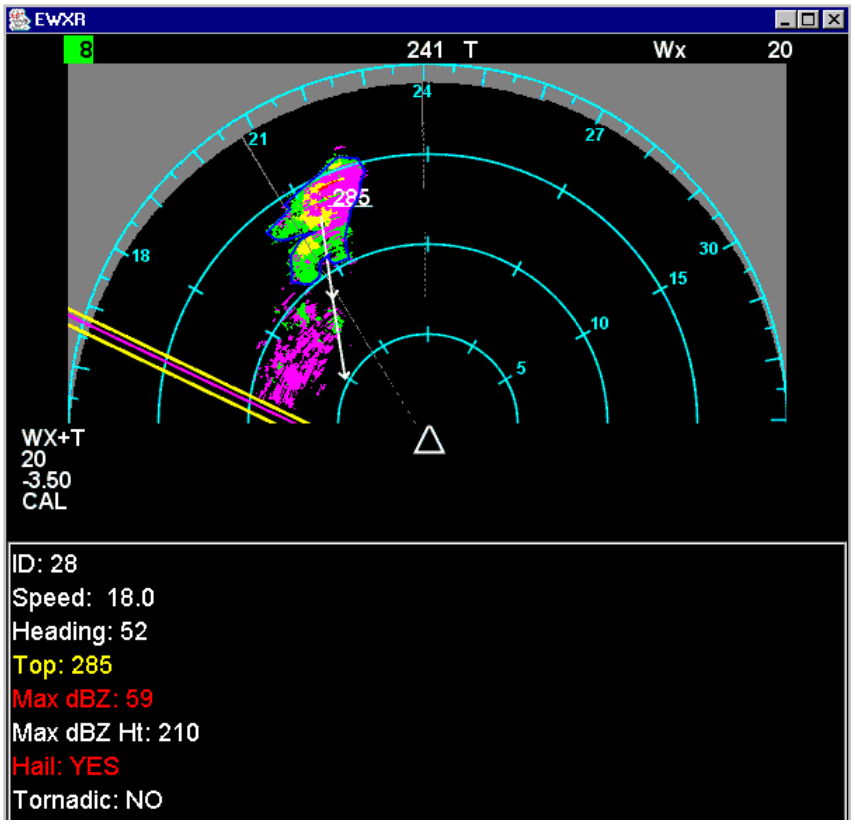


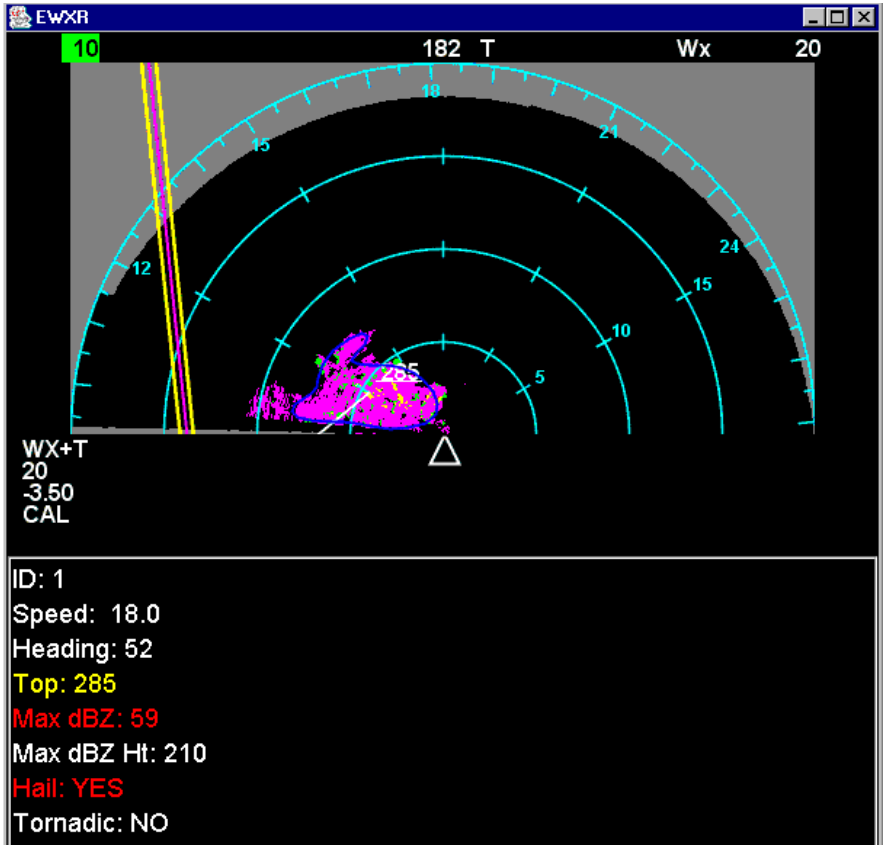
AHAS Strategic Display

AvSP / Weather Accident Prevention / Aviation Weather INformation



Confirmation of flight plan impact prediction: A two-g turbulence encounter





NASA ARIES AHAS/EWxR Flight Tests

AvSP / Weather Accident Prevention / Aviation Weather INformation

Flight Path Impact Prediction

May 17, 2002

AHAS Summary

- AHAS Benefits
  - AHAS is an enhanced weather analysis and display tool, integrating text-based and graphical weather data (both data-linked and sensor-based) in the context of a specific mission and equipment profile
  - AHAS uses decision analytic tools to assess and automatically alert pilot to relevant weather hazards
  - Displays of datalinked weather information in both strategic (map) and tactical (track-up, combined with airborne weather radar) were developed and shown to work in real-time

FY-03 Flight Experiment Plans

AvSP / Weather Accident Prevention / Aviation Weather INformation

- AHAS is being further developed under a task with Georgia Tech Research Institute (GTRI) with Rockwell Scientific and Rockwell Collins as subcontractors
- Software and hardware upgrades are underway
  - Cockpit Display
  - Computer Upgrades
  - Extend Client/Server Architecture
- FY-03 AHAS Flight Experiment Objectives
  - Assessment of AHAS weather information with real weather
  - Incorporate new National Convective Weather Forecast (NCWF) and Diagnostic (NCWD) products
  - Evaluate NEXRAD versus NCWD/F attribute data
  - Piloted assessment of AHAS decision aids
  - Usability feedback on AHAS display formats

Conclusions

- **AHAS is a prototype AWIN system**
  - Builds on technologies developed under AWARE and EWxR Cooperative Research Agreements
  - Supports AWIN research on cockpit use of graphical weather products and decision aiding by intelligent analysis of weather information
  - Flight tests on NASA B-757 ARIES in FY-02 support utility and continued development
  - Piloted evaluations on ARIES planned for FY-03
  - Applications to future AWIN simulation and flight experiments for ground and airborne users in both Transport and GA are being considered

Appendices:
AWARE and EWxR CRAs

Aviation Weather Awareness and Reporting Enhancements:

AWARE et al - context sensitive display of hazards

Decision Analysis & Usability Studies

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AWARE Outline

AvSP / Weather Accident Prevention / Aviation Weather INformation

- Relationship of three AWARE-based projects
- Screen shots of AWARE in operation
- Discussion of Decision Analysis
- Screen shots of AHAS, AWARE-Dispatcher, including impact on Decision Analysis
- Usability studies: formal and walkthroughs

AWARE, AHAS, AWARE Dispatcher

- AWARE: General Aviation, web-based Pre-Flight briefing
- AHAS: Augmented and modified for in-cockpit (real-time)
- AWARE Dispatcher: dispatcher support (parallel flights)

All featuring context-sensitive
automated hazard alerting
based on
decision analysis techniques
(Bayesian Network model)

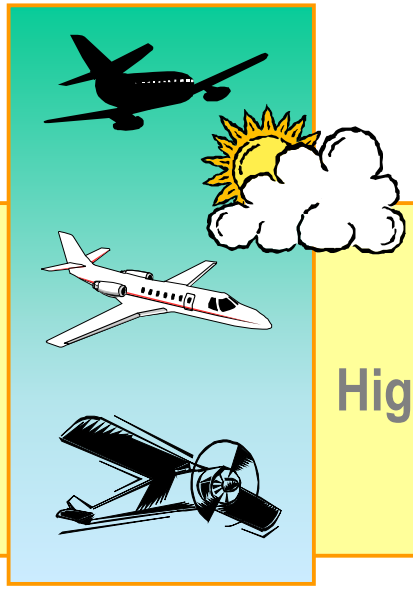
AWARE, AHAS, AWARE Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation

Initially implemented for General Aviation, web-based Pre-Flight briefing
Augmented and modified for commercial in-cockpit (real-time)
and commercial dispatcher support

Preflight Briefing **vfr** **ifr** **lifr**

FY'99 FY'00 FY'01 FY'02



Intended Users:
High-End and Low-End
General Aviation

AWARE, AHAS, AWARE Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation

Initially implemented for General Aviation, web-based Pre-Flight briefing
Augmented and modified for commercial in-cockpit (real-time)
and commercial dispatcher support

Preflight Briefing vfr ifr lifr

FY'99 FY'00 FY'01 FY'02

In-Flight Situational Awareness

Intended Users:
In-cockpit
Commercial Transport

AWARE, AHAS, AWARE Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation

Initially implemented for General Aviation, web-based Pre-Flight briefing
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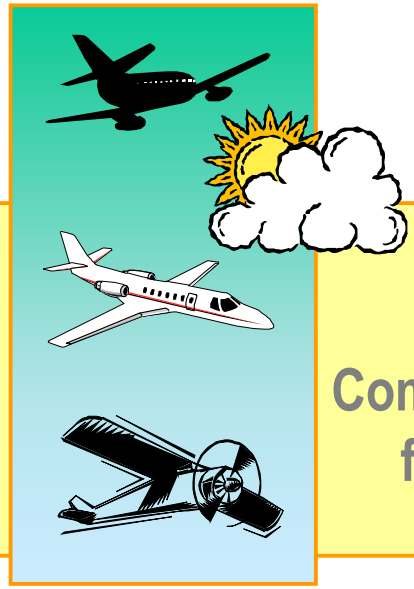
Preflight Briefing vfr ifr

FY'99 FY'00 FY'01 FY'02

In-Flight Situational Awareness

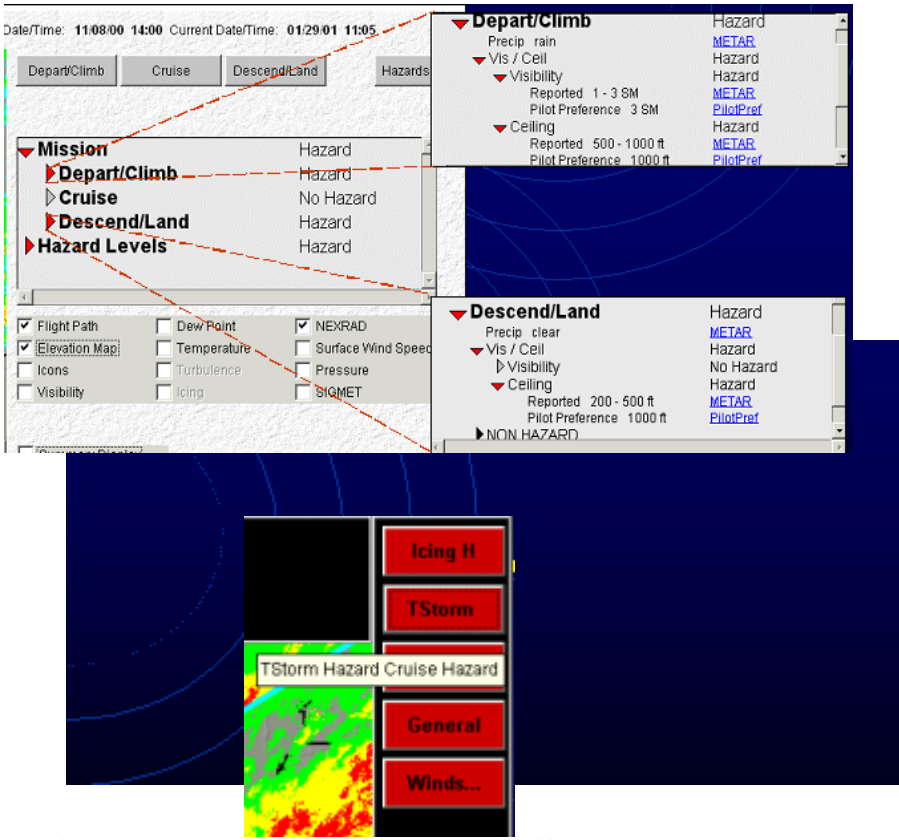


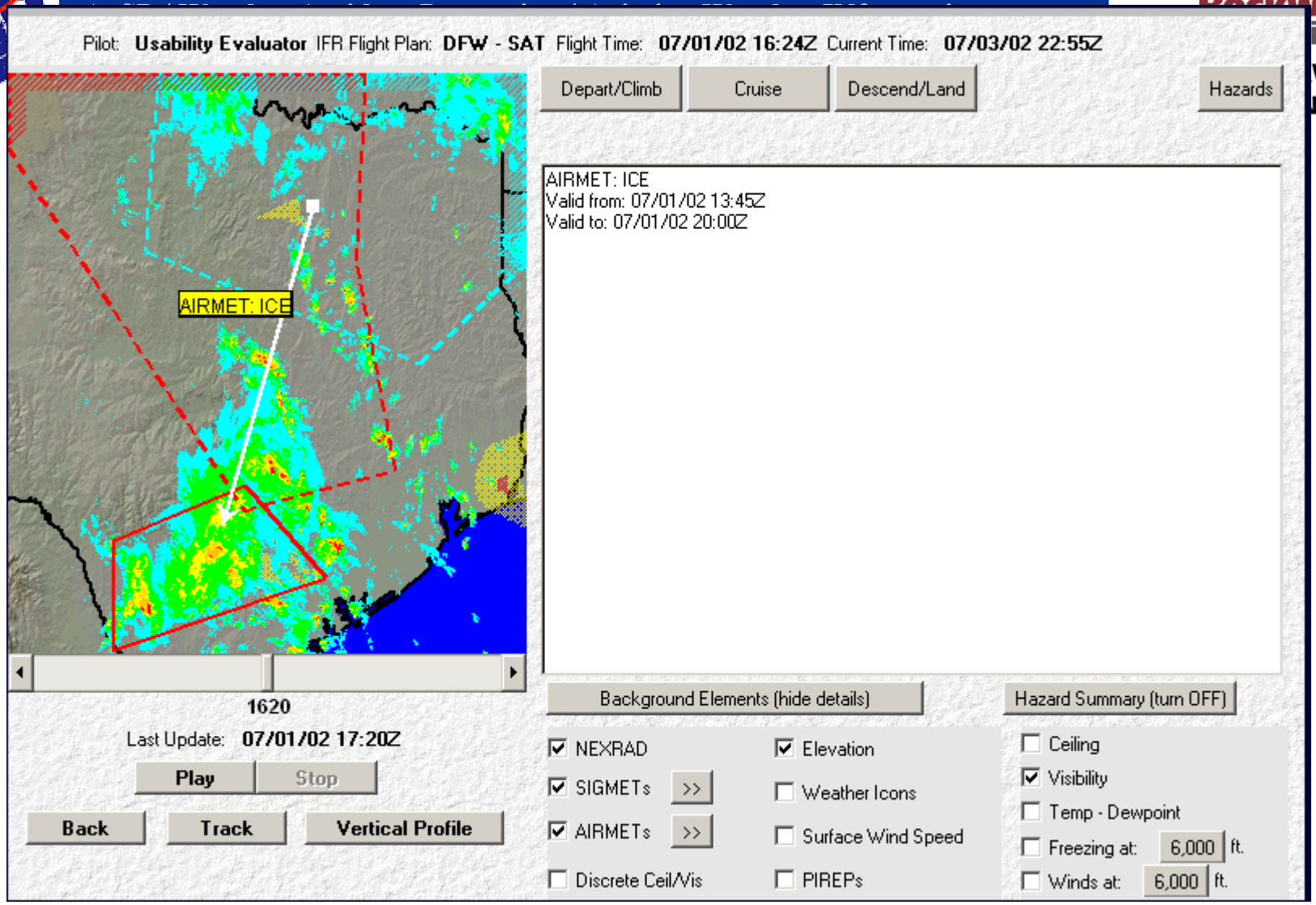
Intended Users:
Commercial dispatchers
for multiple flights

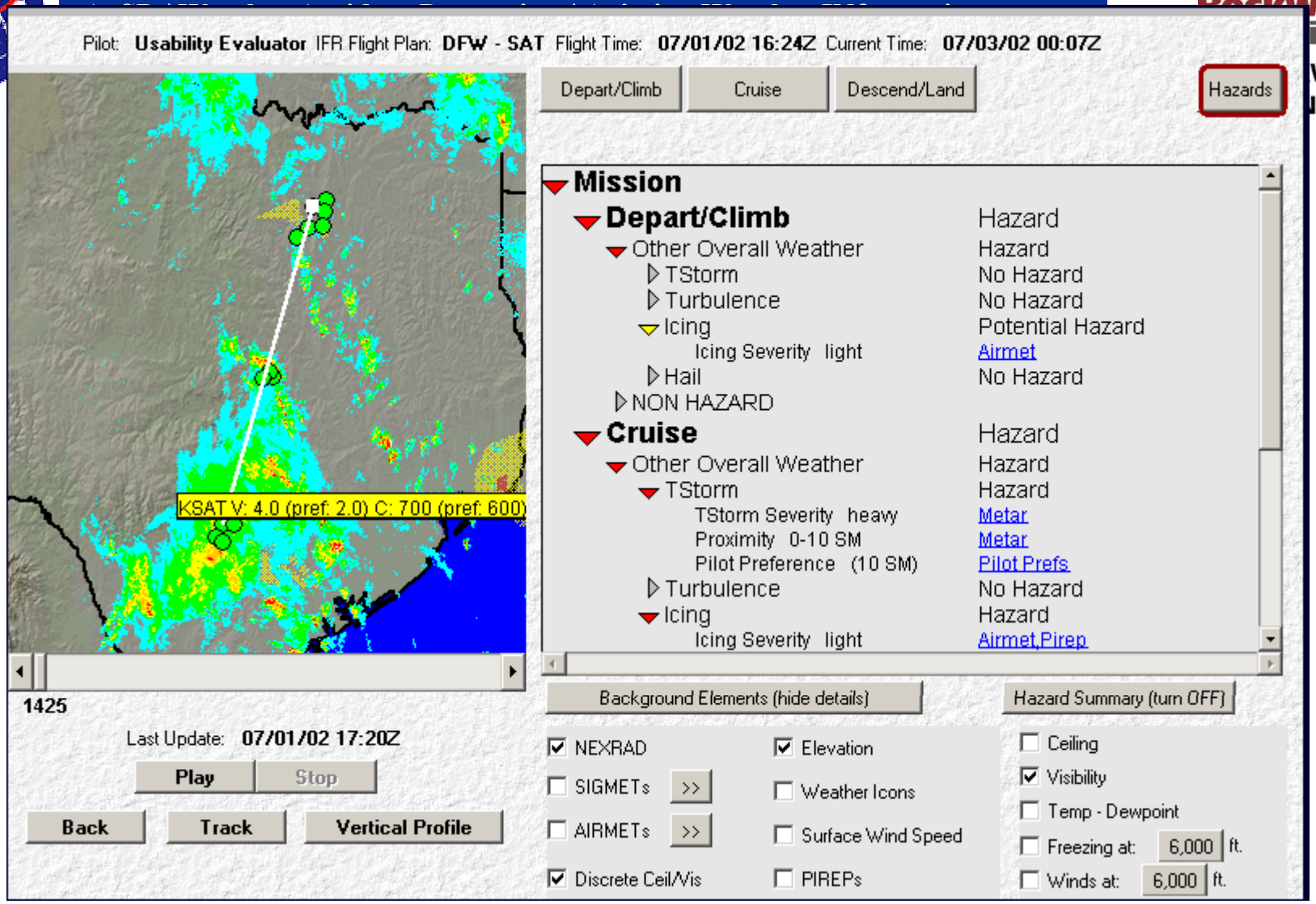
AWARE Decision Analysis Strength

AvSP / Weather Accident Prevention / Aviation Weather INformation

- AWARE projects all have the advantage of an underlying decision analysis model to evaluate, under uncertainty, multiple sources of weather within the context of the specific mission.
- Using this underlying capability, AWARE can perform hazard analysis, determining whether context-sensitive hazards exist
  - Pilot/dispatcher preferences
  - Aircraft constraints
  - The specific flight plan.



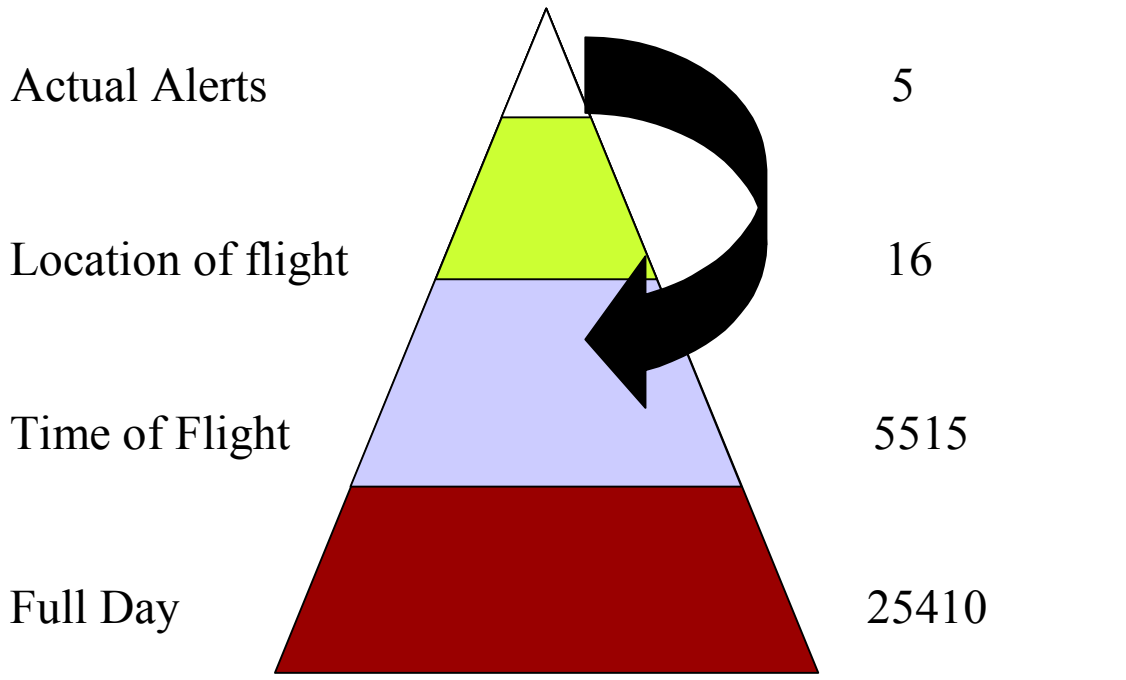

Pilot: Usability Evaluator IFR Flight Plan: DFW - SAT Flight Time: 07/01/02 16:24Z Current Time: 07/03/02 22:55Z
Depart/Climb
Cruise
Descend/Land
Hazards
AIRMET: ICE
Valid from: 07/01/02 13:45Z
Valid to: 07/01/02 20:00Z
AIRMET: ICE
1620
Last Update: 07/01/02 17:20Z
Play
Stop
Back
Track
Vertical Profile
Background Elements (hide details)
Hazard Summary (turn OFF)
NEXRAD
SIGMETs
AIRMETs
Discrete Ceil/Vis
Elevation
Weather Icons
Surface Wind Speed
PIREPs
Ceiling
Visibility
Temp - Dewpoint
Freezing at: 6,000 ft.
Winds at: 6,000 ft.


Pilot: Usability Evaluator IFR Flight Plan: DFW - SAT Flight Time: 07/01/02 16:24Z Current Time: 07/03/02 00:07Z
Depart/Climb
Cruise
Descend/Land
Hazards
KSAT V: 4.0 (pref: 2.0) C: 700 (pref: 600)
Mission
Depart/Climb Hazard
Other Overall Weather Hazard
TStorm No Hazard
Turbulence No Hazard
Icing Potential Hazard
Icing Severity light Airmet
Hail No Hazard
NON HAZARD
Cruise Hazard
Other Overall Weather Hazard
TStorm Hazard
TStorm Severity heavy Metar
Proximity 0-10 SM Metar
Pilot Preference (10 SM) Pilot Prefs
Turbulence No Hazard
Icing Hazard
Icing Severity light Airmet,Pirep
1425
Last Update: 07/01/02 17:20Z
Play
Stop
Back
Track
Vertical Profile
Background Elements (hide details)
Hazard Summary (turn OFF)
NEXRAD
SIGMETs
AIRMETs
Discrete Ceil/Vis
Elevation
Weather Icons
Surface Wind Speed
PIREPs
Ceiling
Visibility
Temp - Dewpoint
Freezing at: 6,000 ft.
Winds at: 6,000 ft.

AWARE Decision Analysis

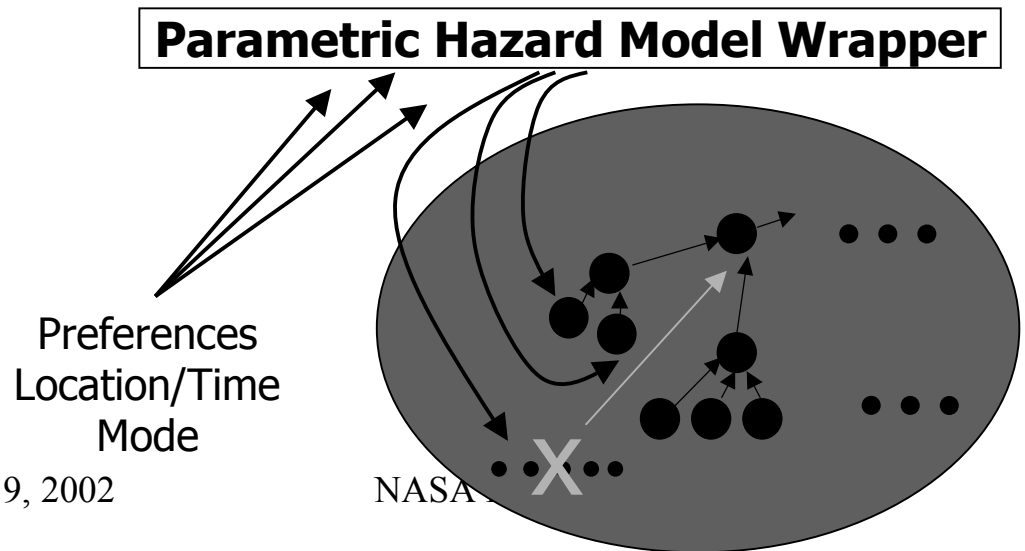
AvSP / Weather Accident Prevention / Aviation Weather INformation

- One aspect of information filtering
- Applies user/equipment constraints
  - Pilot/dispatcher preferences
  - Aircraft constraints
- User still has access to raw data, for completeness



Decision Analysis Challenge

- Model is large, complex; must be reusable…
  - Must be able to represent GA (VFR, IFR), Commercial Pilots, Dispatchers
- Solution: Wrapper, mission parameter based
  - Commonality: flightpath, timeframes, personalization
  - Determines/applies mode, preferences, spatial-temporal context; relevance of submodels



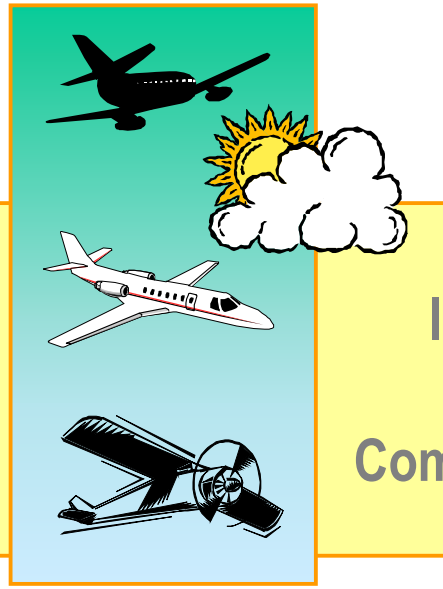
AWARE, AHAS, AWARE-Dispatcher

Initially implemented for General Aviation, web-based Pre-Flight briefing (AWARE) **Augmented and modified for commercial in-cockpit (real-time)**
and commercial dispatcher support

Preflight Briefing vfr ifr

FY'99 FY'00 FY'01 FY'02

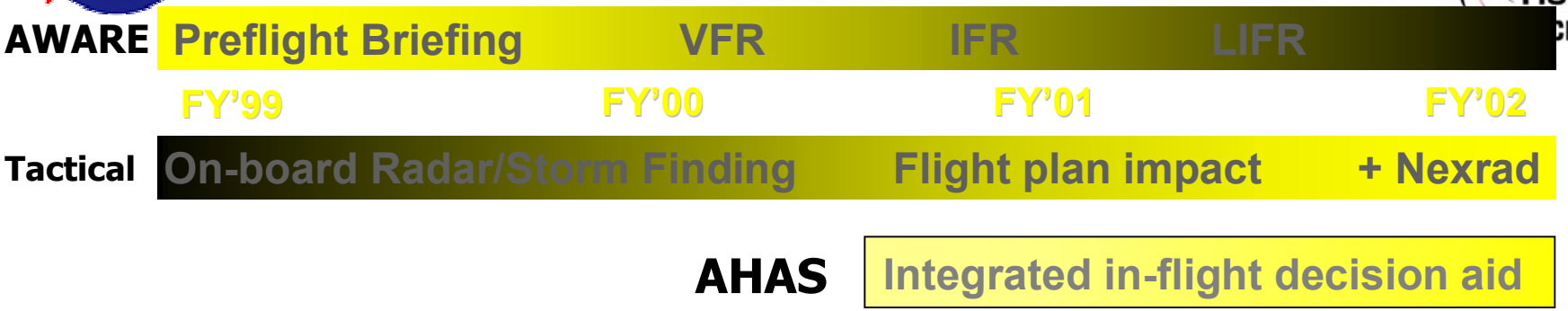
In-Flight Situational Awareness



Intended Users:
In-cockpit
Commercial Transport

AWARE, AHAS, AWARE-Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation



- AHAS -
  - In-cockpit graphical data presentation for situational awareness
    - Hazard analysis top level presentation
    - Details available in drill-down mode
  - Decision analysis based hazard alerts, strategic and tactical "intelligent assessment of hazards"

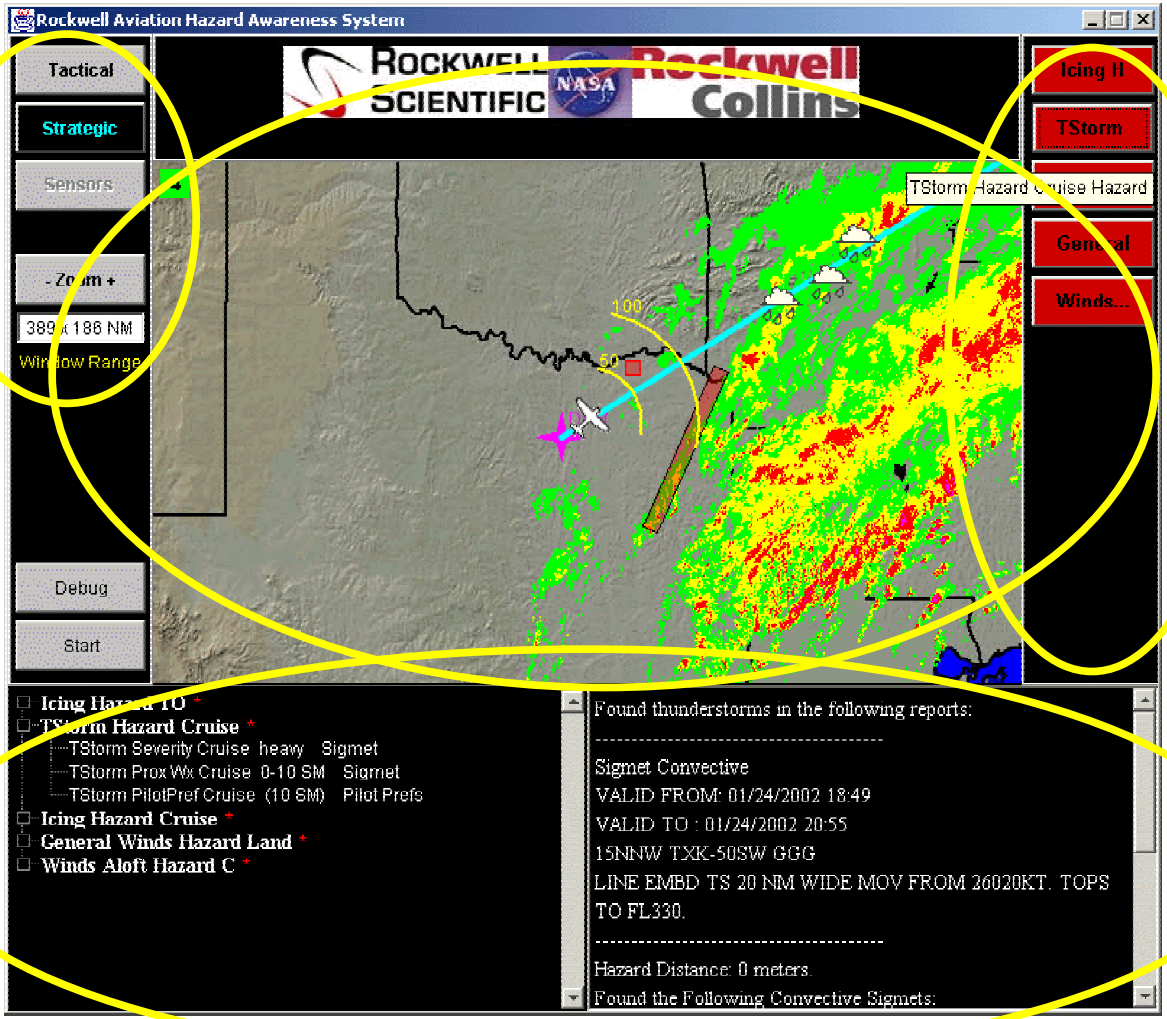
AHAS – In Cockpit

AvSP / Weather Accident Prevention / Aviation Weather INformation

Primary Display – Strategic mode similar to AWARE

Mode control:

Strategic or Tactical

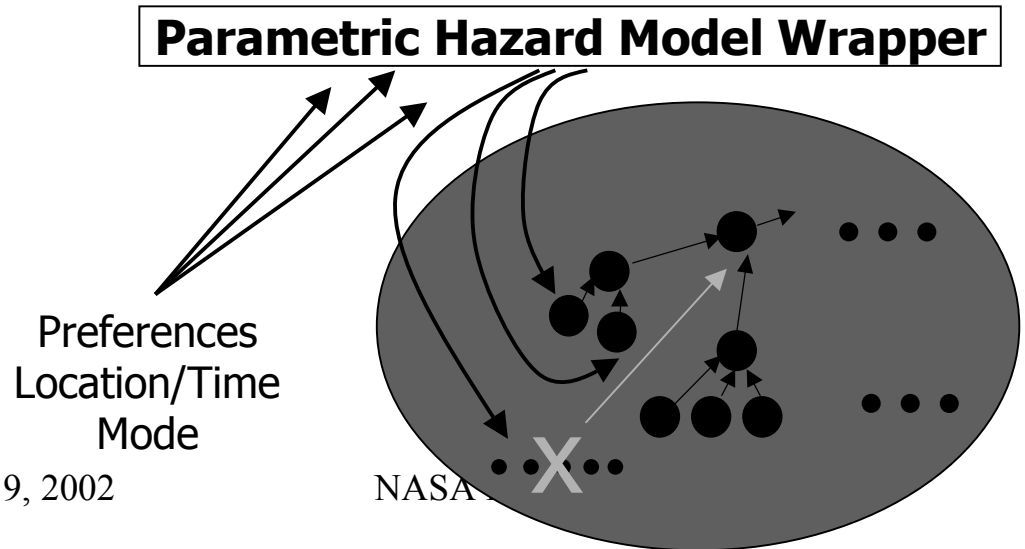


Alerts

Secondary Displays: Decision Analysis & data source

Decision Analysis Challenge

- Model is large, complex; must be reusable…
  - Must be able to represent GA (VFR, IFR), **Commercial Pilots**, Dispatchers
- Solution: Wrapper, mission parameter based
  - Augmented with WindsAloft
  - Removed visibility/ceiling hazards enroute (still visualized)
  - Utilize LIFR settings for preferences rather than VFR/IFR
  - Timeframe is present-data only



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and commercial dispatcher support

Preflight Briefing **vfr** **ifr**

FY'99 FY'00 FY'01 FY'02

In-Flight Situational Awareness

Intended Users:
Commercial dispatchers
for multiple flights

AWARE, AHAS, AWARE-Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation

AWARE Preflight Briefing VFR IFR LIFR Dispatcher

FY'99 FY'00 FY'01 FY'02

AWARE Dispatcher implements a parallel flight weather hazard alerting system

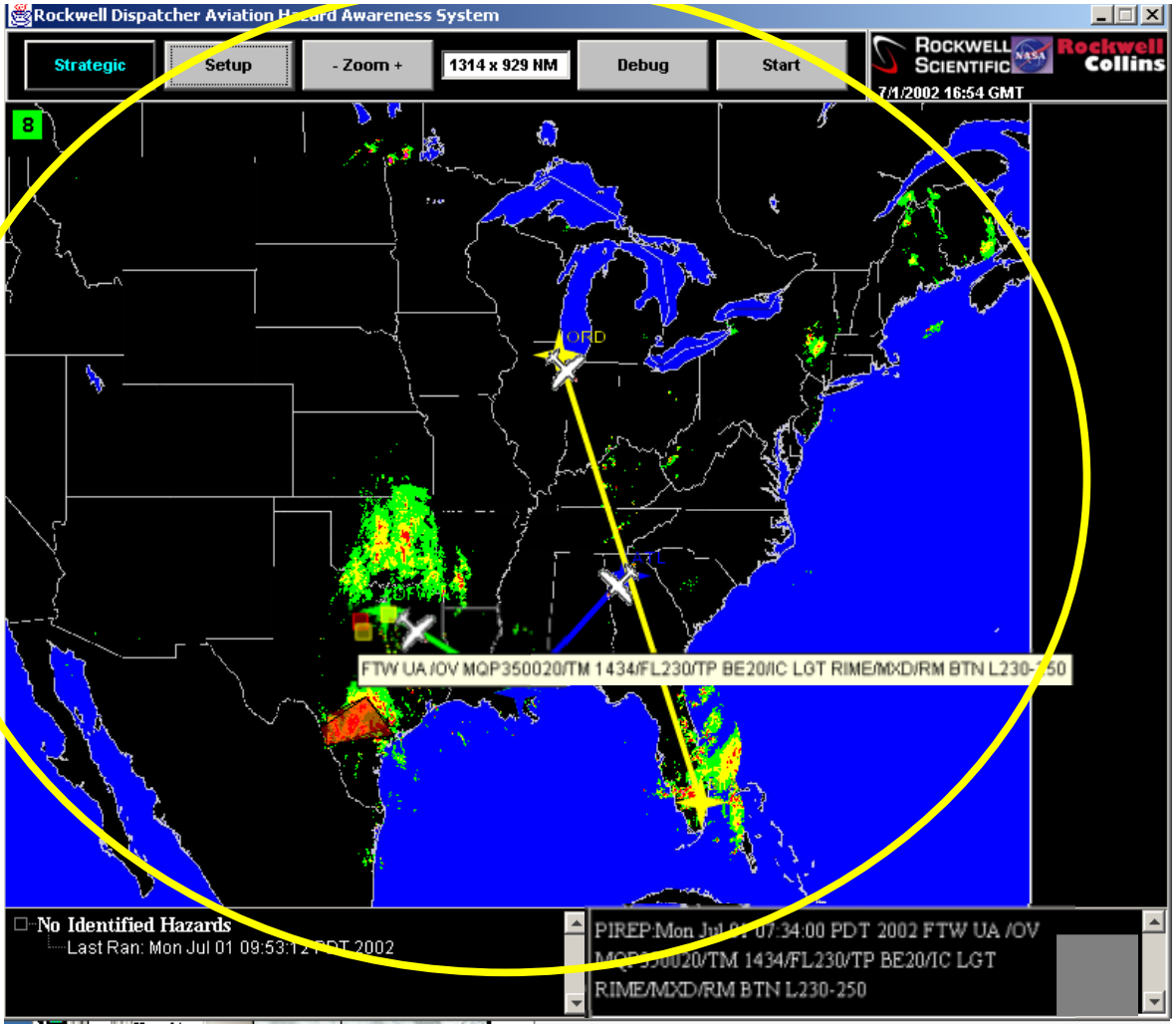
- Automatic notification of hazards for multiple flights
- Display and relevant alerts for parallel flights
- Generation of alerts specific to dispatcher preferences

Intended Users:
Commercial dispatchers
for multiple flights

AWARE Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation

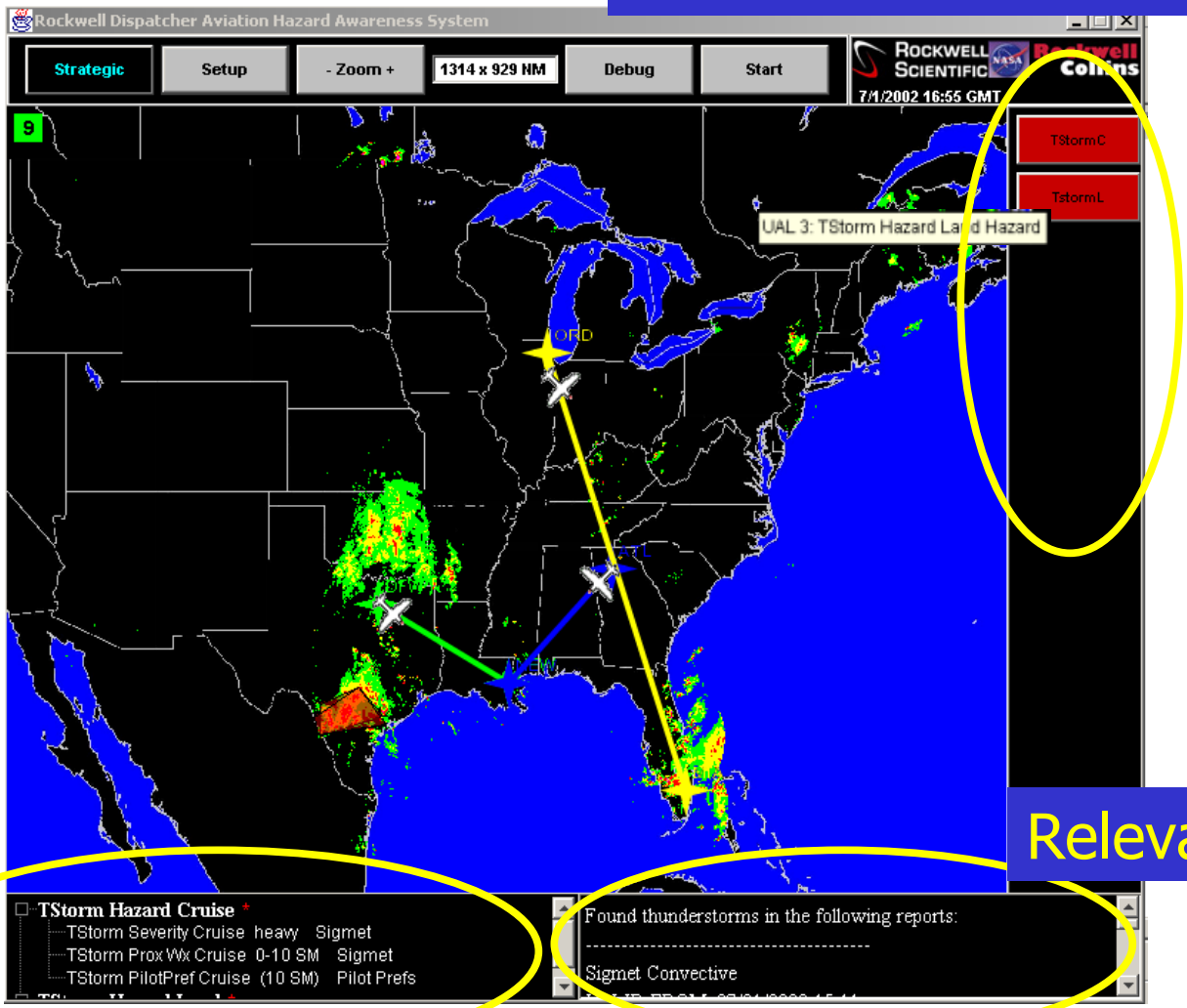
Primary Display – Strategic mode only, AWARE overlay options



AWARE Dispatcher

AvSP / Weather Accident Prevention / Aviation Weather INformation

Alerts – identifiable with mouse-over; associated with text below

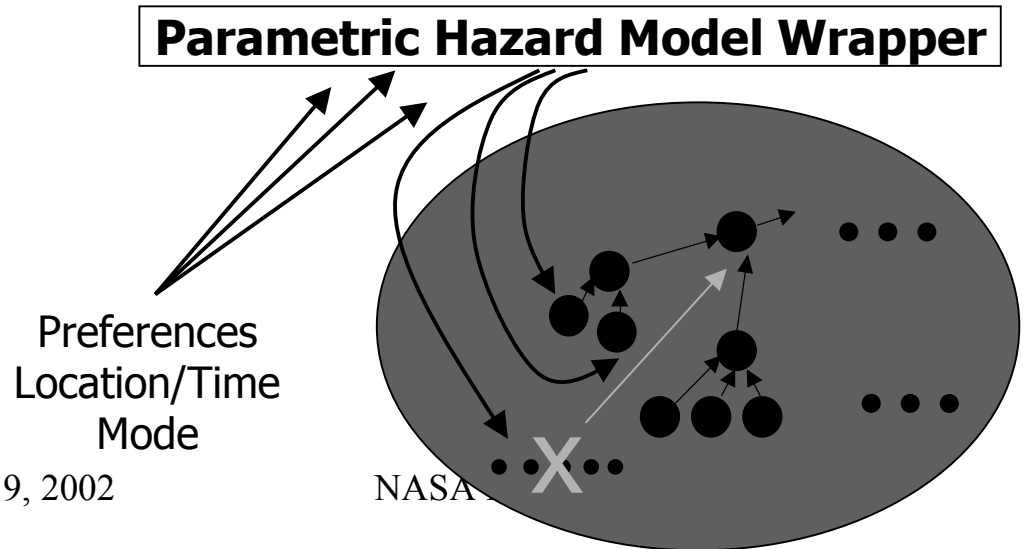


Overall Hazard results, plus triggers

Relevant Text

Decision Analysis Challenge

- Model is large, complex; must be reusable…
  - Must be able to represent GA (VFR, IFR), Commercial Pilots, Dispatchers
- Solution: Wrapper, mission parameter based
  - Instantiation of model per flight
  - Preferences based on dispatcher setup
  - Timeframe is current time



Usability Testing

- AWARE –
  - Formal testing for both VFR & IFR modes
  - 6 subjects, 4 flight plans; 2 test methods
  - 2 visits for comparable evaluations of flights

- AHAS, AWARE-Dispatcher
  - Walk throughs for design / evaluation

Usability test method: DUAT

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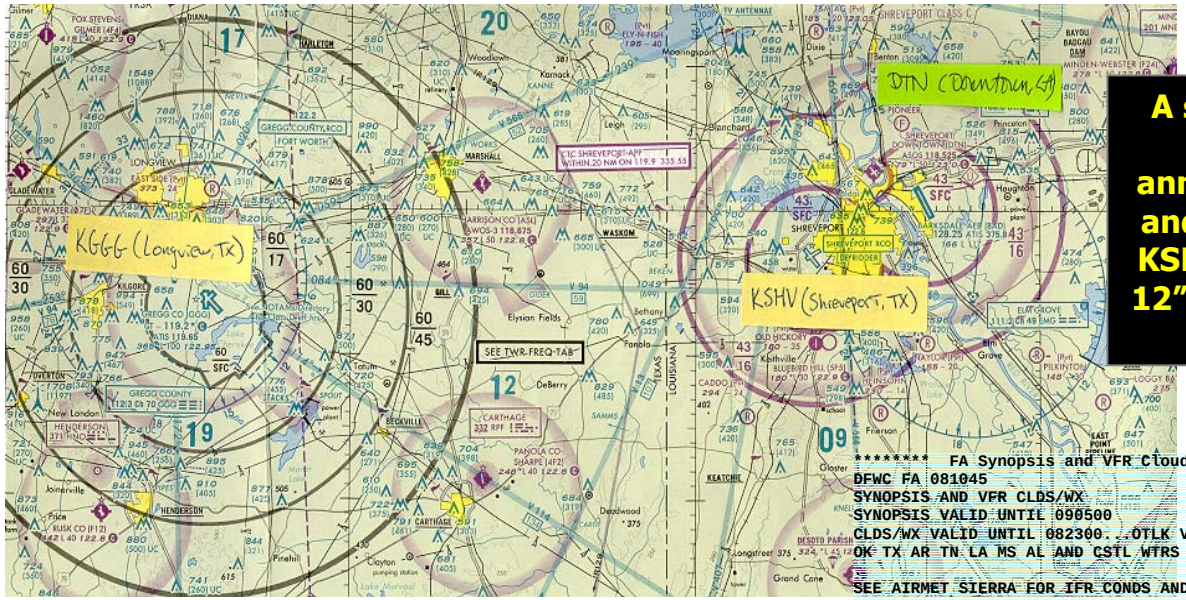


A subset of the sectional near the destination airport, with annotations for destination (KDTN) and other weather sources (KGGG, KSHV). It measures approximately 12" x 6"; all sectionals for this flight measure approx 36" x 12".

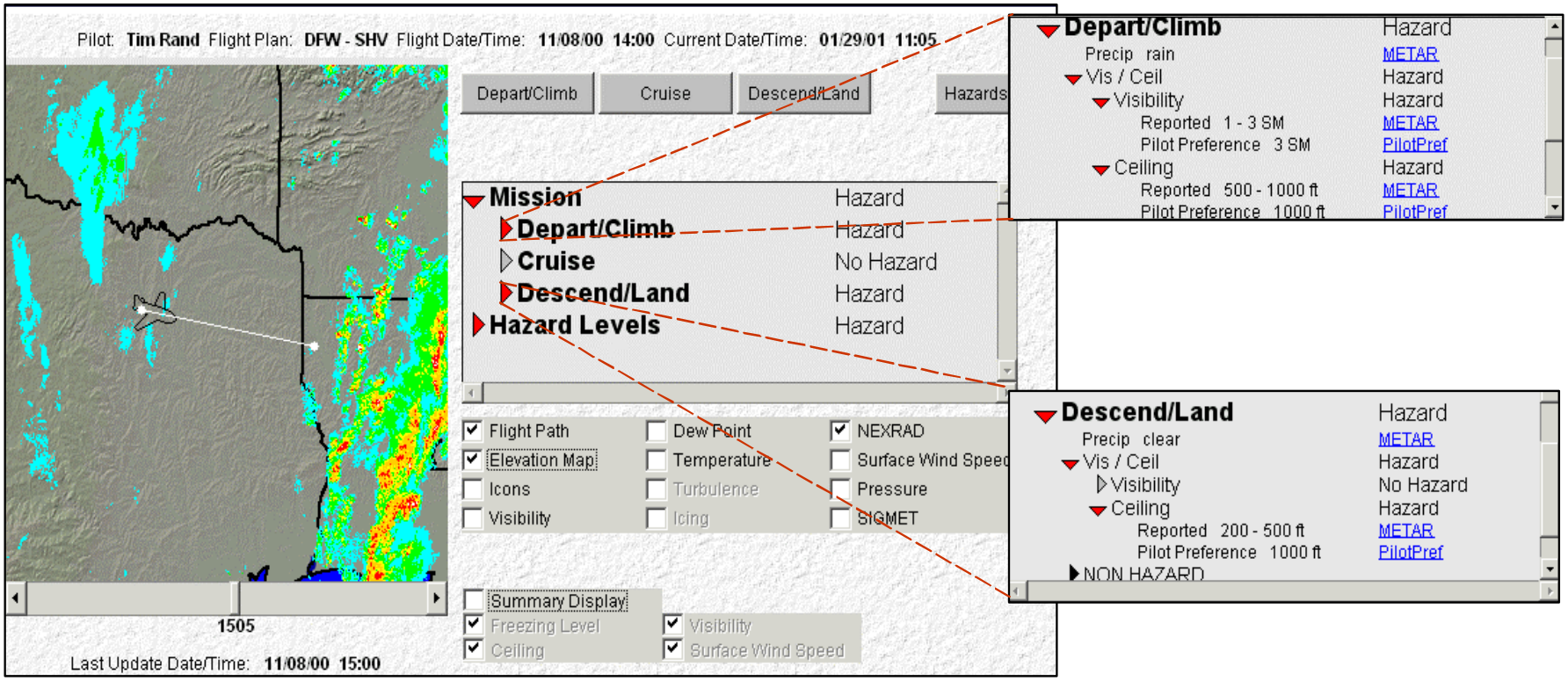
```
********  FA Synopsis and VFR Clouds/Weather  ********
DFWC FA 081045
SYNOPSIS AND VFR CLDS/WX
SYNOPSIS VALID UNTIL 090500
CLDS/WX VALID UNTIL 082300...OTLK VALID 082300-090500
OK TX AR TN LA MS AL AND CSTL WTRS

SEE AIRMET SIERRA FOR IFR CONDS AND MTN OBSCN.
TS IMPLY SEV OR GTR TURB SEV ICE LLWS AND IFR CONDS.
NON MSL HGTS DENOTED BY AGL OR CIG.
.
SYNOPSIS...AT 11Z CDFNT DXO-BNA-JAN BECMG QSTNRY JAN-BRO LN.
WRMFNT LOZ-GQO-ATL LN. BY 05Z LOW PRES NERN LA WITH CDFNT MLU-
LCH-60S BRO LN AND WRMFNT MLU-LOU-DXO LN. TROF ELD-TUL LN. DSIPTG
QSTNRY FNT APE-VXV-ATL LN. HIGH PRES SWRN TX. ...DARRAH...
.
.
.
KNFW 081855Z 33011KT 4SM BR SCT009 OVC015 06/04 A2985 RMK
     SLP107 T2 SET T00600040
KNFW 081905Z 33015KT 3SM BR BKN009 OVC015 06/04 A2985 RMK
     SLP107 T2 SET
METAR KFTW 081853Z 33011KT 7SM OVC012 05/04 A2983 RMK AO2 SLP104
    T00500039
SPECI KFTW 081908Z 33011KT 7SM FEW008 OVC016 05/04 A2984 RMK AO2
SPECI KFTW 081921Z 32013KT 5SM BR BKN008 OVC016 05/04 A2983 RMK AO2
    CIG 006V011
METAR KAFW 081853Z 35012KT 5SM BR OVC011 06/04 A2986 RMK AO2 PRESFR
    SLP115 T00560044
```

A small subset of the DUAT for that flight; the entire document is 39 pages long.

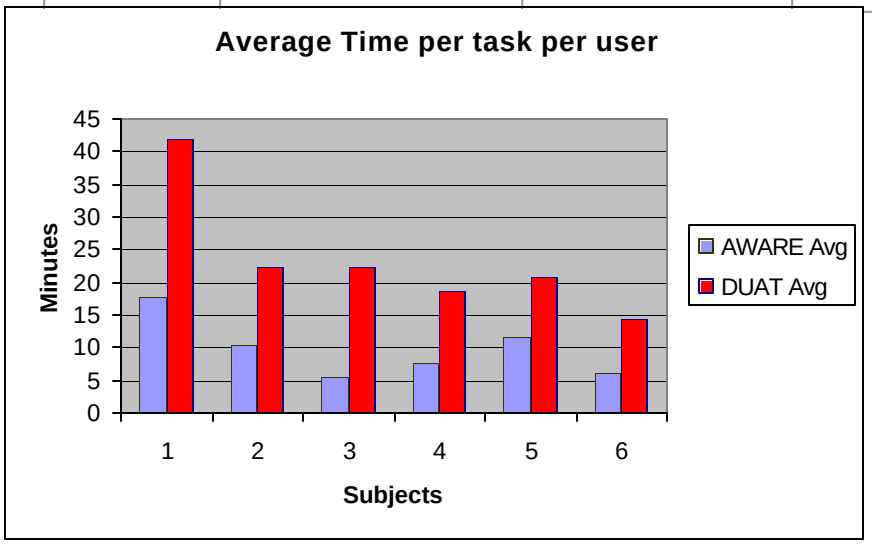
Usability test method: AWARE

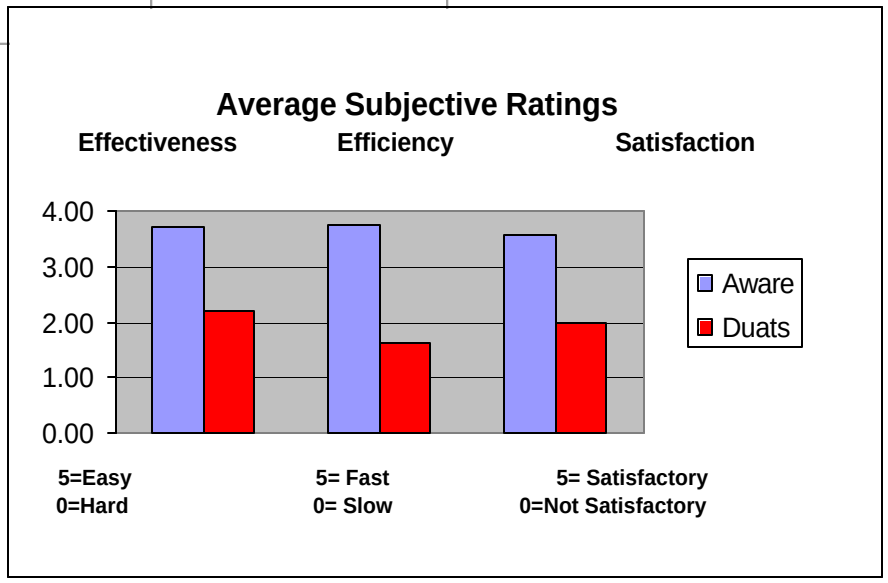
AvSP / Weather Accident Prevention / Aviation Weather INformation



AWARE: Objective/Subjective Results

Flight	A	B	C	D
AWARE	All subjects found all hazards	All subjects found all hazards	All subjects found all hazards	All subjects found all hazards
DUAT	All subjects missed IFR airmet, found all other hazards	1 found sigmet; others found all but sigmet	All found all hazards	3 missed visibility due to IFR airmet





Additional AWARE usability results

- Enthusiasm of pilots
  - Sigmet/Airmet boundaries
  - Hazard analysis with graphics, Nexrad animation
  - “Can I have it now?”
- Suggestions for modifications
  - UI, model variations
- Suggestions for next steps
  - VFR for IFR, IFR for LIFR…

- United Flight Operations
  - Initial display format evaluations
    - Iterative prototyping of extended system
      - Navigation, level of detail, value of overlays
      - Mouse over
- Flight test experimental testing
  - Forms complete; limited by pilot availability

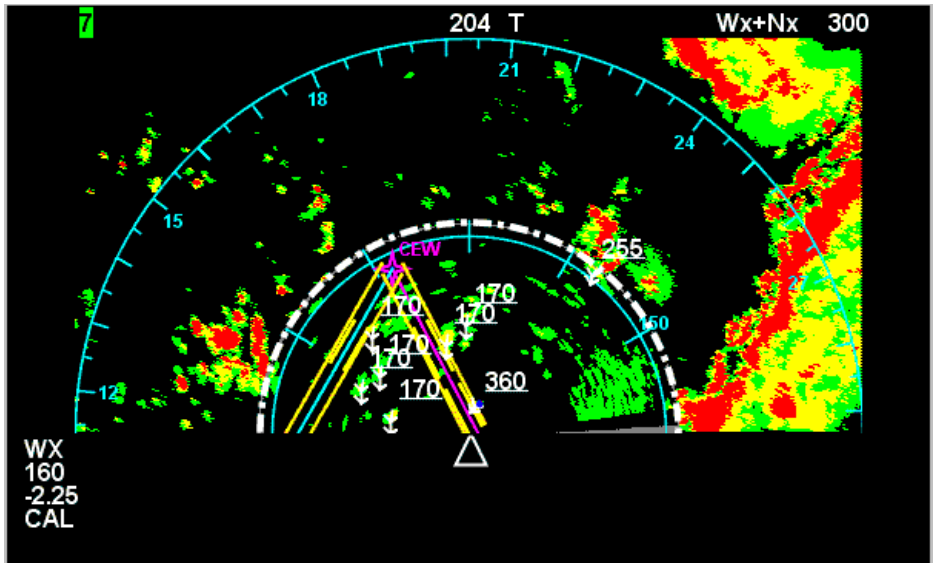
AWARE Dispatcher Usability Studies

AvSP / Weather Accident Prevention / Aviation Weather INformation

- United Dispatcher Center (World Headquarters)
  - Determine relevance of AWARE, AHAS-like display and hazard alerts for multiple flights
    - Automatic Alerting, tailored to the dispatcher
    - Larger display format, multiple flight ID
    - Data by altitude, graphical Pireps
  - Iterative prototyping display, automatic alerts
    - Automatic Alerting for complex situations
      - Data not easily visualized
      - Combinations of parameters
      - Evaluations requiring calculations
    - Display advantages; merge with existing
- American Airlines

Enhanced Weather Radar System

Kevin Kronfeld, Rockwell Collins



Enhanced Weather Radar (EWxR):

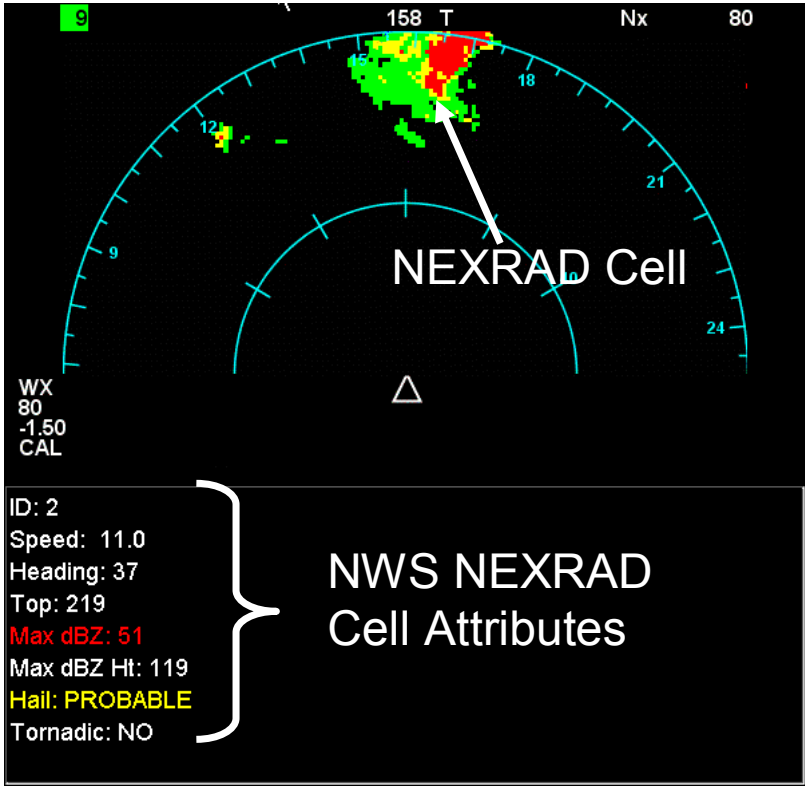
Create an integrated weather advisor that controls and interprets the weather radar as a human expert would.

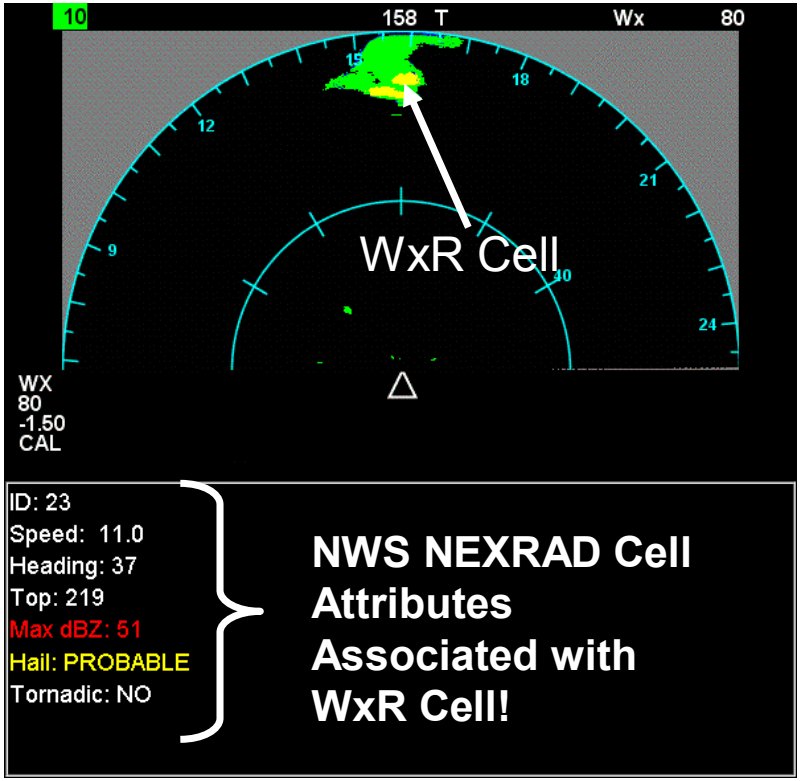
EWxR Technology

- WxR Assistant
- Automated Storm Finding WxR
- Real-time WxR image processing
  - Extract storm cells from WxR imagery
- Data Correlation/Fusion
  - Fuse information about a storm cell from multiple sensors and data sources.
- Decision Aids
  - Automatically assess whether a cell is hazardous and will affect the pilot's mission.

EWxR Data Correlation/Fusion

AvSP / Weather Accident Prevention / Aviation Weather INformation





September 2002

- Collins Business and Regional Systems (BRS) and Weather Services International (WSI)provided SATCOM datalink.
- WSI, Collins weather service partner, provided weather data to the aircraft.

Sabreliner Flight Test

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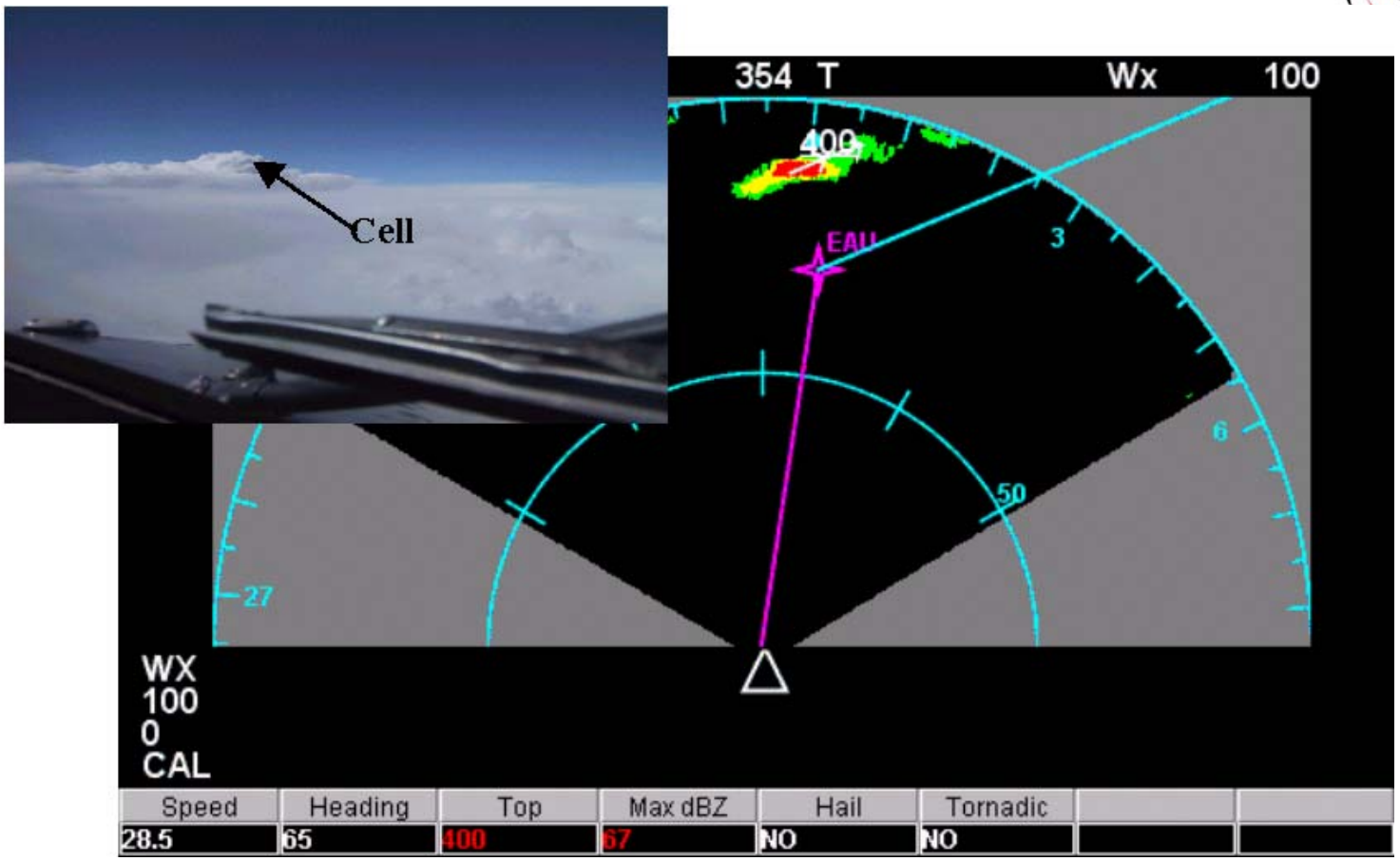
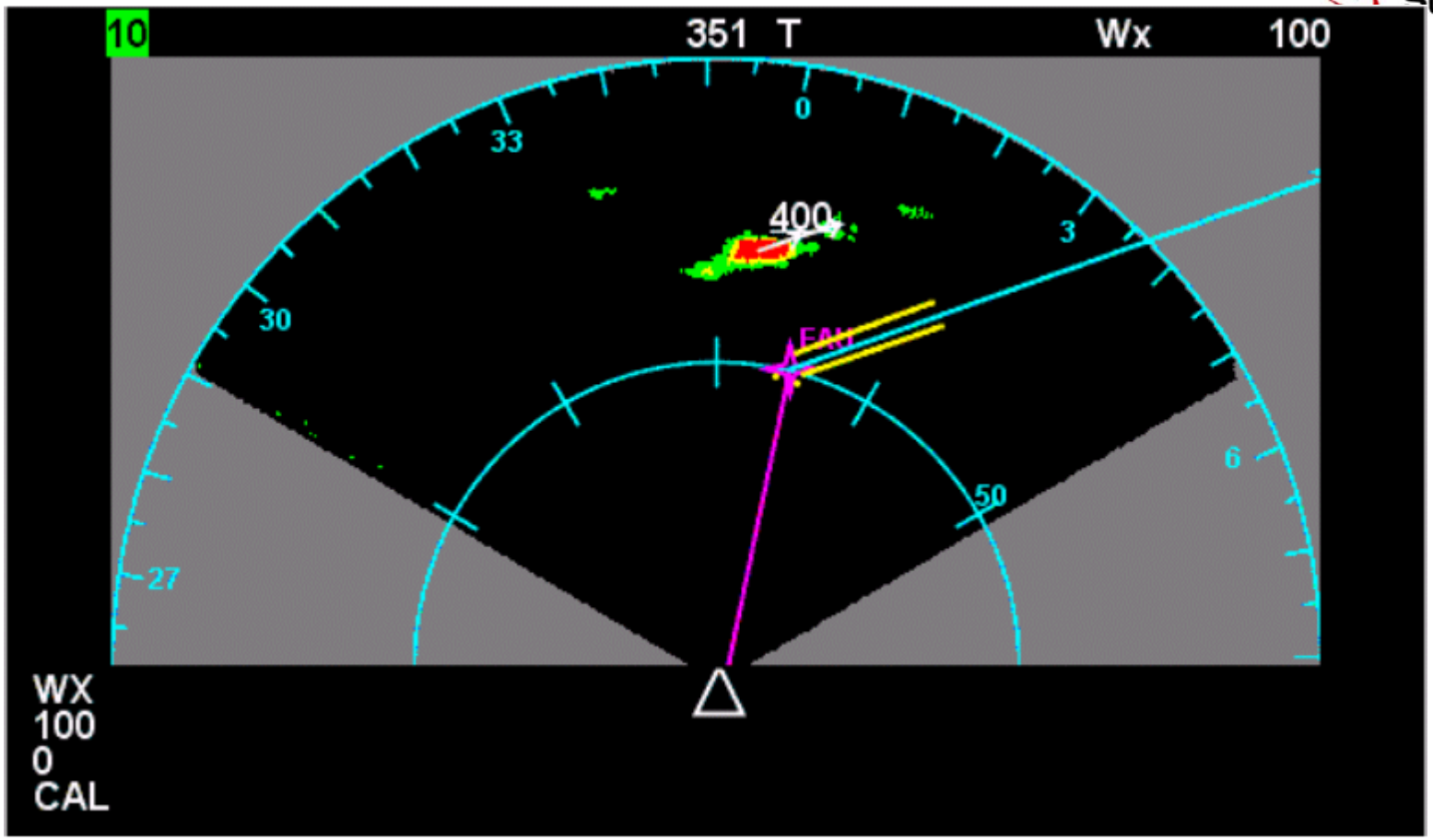


Hazard Assessment - September 5, 2002

Sabreliner Flight Test

AvSP / Weather Accident Prevention / Aviation Weather INformation



Flight Path Impact Prediction - September 5, 2002

Leverage existing EWxR technology for additional aviation weather research.

- Integrated into NASA's Airborne Hazard Avoidance System (AHAS).
- Build upon existing tactical decision aids to automatically assess hazardous weather as new national and international weather information is available.
  - Enhanced Hazard Assessment and Flight Path Impact prediction.